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AND ABSTRACT OF THE LITERATURE

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The JOURNAL *of* INDUSTRIAL HYGIENE

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INDUSTRIAL MEDICINE AND SURGERY—A RÉSUMÉ OF ITS DEVELOPMENT AND SCOPE*

HARRY E. MOCK, M.D.

Lieut. Col., M. C., U. S. A., Office of the Surgeon General, Division of Reconstruction of Disabled Soldiers, and formerly Chief Surgeon of Sears, Roebuck Co.

THE last decade has witnessed the birth of a new specialty in the medical profession—Industrial Medicine and Surgery. The majority of specialties in medicine tend to develop the physician along some specific line to the exclusion of the other branches of practice. To this highly specialized study the great scientific advancements in medicine owe their origin. On the other hand specialization has had a decidedly narrowing influence upon the great leaders of the profession causing them to lose sight of the human side of their work, exemplified so pre-eminently by the old-time family physician.

This new specialty of industrial medicine and surgery includes every scientific branch of medicine and in addition requires a keen understanding of practical sociology. Its field is so broad that it involves specialists within this specialty—yet each worker in this field must be thoroughly trained in its general aspects.

The problems of the family physician concerned the individual and the family. The problems presented to the industrial physician concern the individual, the family, and the large group associated with him—his fellow-employees and employer.

Specifically the scope of this work deals with the human maintenance equation in industry. It involves the prevention of disease and accidents among the entire group of employees; the constant supervision of the health of the employees, including a study of each individual, the working conditions, the hazards of each occupation, the question of hours of labor and wages, the daily intercourse between the employer and the employed as well as between fellow-employees, and the home environments of the working force; adequate medical and surgical care of the sick and injured; compensation and benefits during periods of disability; the selection of occupations according to the physical qualifications of the individual; the restoration of the disabled to an economic usefulness; it involves, in fact, every human equation in this problem which affects the health and efficiency of the individual or of the entire group of employees.

With the development of this specialty we are approaching nearer and near the ideal expressed by Juhnke when he said: "And the end is that the workman shall live to enjoy the fruits of his labor; that his mother shall have the comfort of his arm in her age; that his wife shall not be untimely a widow; that his children shall have a father; and that cripples and helpless wrecks who were once strong men, shall no longer be a by-product of industry."

As each country entered the great world war it was confronted with two all-important necessities, the conservation of manpower and maximum production in the essential industries. Our nation was confronted with the same problems. At first, in the great efforts to overcome our unpre-

*Received for publication April 1, 1919.

paredness, we were prodigal to the extreme, especially in the matter of conserving the forces of our industrial army.

But more and more as the months went by, the principles of industrial medicine and surgery came to be recognized as essential in procuring maximum production. From a specialty known only to a few hundred physicians and whose value was recognized only by those industries employing medical services, it rapidly became a measure in the national preparedness program. To-day the language of the industrial physician is spoken familiarly by thousands of physicians and laymen.

With the prospect of hundreds of thousands of maimed soldiers being returned to our shores from the conflict overseas, the government began to prepare for the reconstruction of these disabled men. Here again, industrial surgery found a field for the application of principles demonstrated as practical and sound in a few of our great industries. But the work of reclaiming the disabled soldiers has gone far beyond the practices in industry; now the broadened principles of this work must be applied to all disabled from industry.

The conservation of man-power and the reclamation of disabled men bid fair to become two of the greatest by-products of this war. Too often in the past the maimed from industry were relegated to the human scrap-heap. They were given mediocre jobs where all incentive for endeavor or future advancement were lacking, or, as often happened, they were allowed to drift with the current into the great army of beggars and derelicts.

The nation is at last awakened to its wasteful attitude toward men disabled from industry. To-day the creed of the disabled soldier will be adopted by the handicapped workers of the land because at last they will be given a chance instead of charity: Once more to be useful—to see pity in the eyes of my friends replaced with commendation—to work, produce, provide, and to feel that I have a place in the world—seeking no favors and given none—a Man among Men in spite of this physical handicap.

Thus it is quite evident that the specialty of industrial medicine and surgery, is in fact the best medical and surgical practice, the best preventive medicine and preventive surgery, combined with the best social and economic principles, all applied to a large group—the working men and women of our nation—approximately forty million people. With its rapid growth it is becoming the greatest public health service yet offered to our people.

HISTORY OF ITS DEVELOPMENT

This form of public health service was rarely mentioned prior to ten years ago. To-day it is receiving the greatest attention from physicians, industrial engineers, social workers and employers in general. Medical schools and engineering schools are teaching students various phases of industrial medicine and surgery. Every year witnesses the enactment of new laws by state legislatures tending to improve or protect the health, welfare, and comfort of workmen. In fact, few subjects have received such widespread attention, or have reacted for greater good to the nation in so short a time.

For decades certain industries have had their company surgeons. These men, working under contract, usually inadequately paid, and frequently considering their industrial practice as only a side-issue, did not grasp the opportunity for service offered by their positions. As a rule their work was limited to emergency surgery—the repair of the broken human machine after the damage had been done.

In 1911, the writer made a careful study of the various state laws dealing with industry and labor. While a few states had acts covering some of the fundamental principles of health protection among working forces, yet evidently no state had made a serious study of this problem.

The report of the Department of Commerce and Labor for 1909 and a study of the various labor laws showed that only twenty-one states had acts bearing directly upon the subject of factory and work-shop sanitation. Eight of these states, however, limited their vision of the subject to this order, "All work-shops must have proper ventilation and proper sanitary conditions," but none of them made specific recommendations as to what constituted "proper." Six of the twenty-one states designated the amount of air space per person and made a few specific requirements covering sanitary conditions. At least five were very specific in their requirements for the removal of injurious

gases or dusts; two provided for the cleansing of the interior of the work-shops; and one only had a law against overcrowding factories and work-rooms.

Most of these states provided for factory inspectors, but these were all laymen, usually untrained in the scientific principles of protecting the health and limbs of employees. This résumé of the various state labor laws at that time deeply impressed one with the great lack of preventive legislation — legislation which, if enacted and enforced, would greatly reduce the death rate among the wage earners and coincidentally improve the hygienic and economic conditions of every community.

In the eight years since this study was made practically every state in the Union has enacted laws seeking to improve the working conditions of employees. In that short period thirty-seven of our states have enactments on employees' compensation; recently a few have included occupational diseases under the causes for compensation. To-day, at least eight states are considering laws for workmen's insurance against sickness and an equal number for the rehabilitation of disabled workmen.

These various laws have been responsible for the installation of comprehensive medical services in many large industries; they have improved industrial health conditions to a great extent. However, a résumé of the laws to-day still impresses one with the great lack of preventive legislation. The crying need is for a thorough study of this entire field and, instead of piece-meal legislation, the enactment of a standardized law in every state which would cover the absolutely essential features of a comprehensive industrial health service.

Although the legislative advancement along these lines has been slow, yet voluntary efforts by individuals, national organizations, many large industries, and by a few state Departments of Industry and Labor have rapidly advanced this new specialty. Prior to 1909, a few state factory inspectors and a few other individuals had called upon the nation to witness the wastage of human life, due to some of the more blatant unsanitary conditions in industry. Beginning with this year, and especially during 1911 and 1912, a great incentive was given to this subject by the writings of a number of physicians connected with industrial concerns.

These writings dealt chiefly with the subject of physical examination of employees, and with other methods for supervision of their health. One of the earliest examples recorded of a careful effort at supervision of the health of a group of workmen was that made by Dr. Frank Fulton, in Providence, R. I., in 1906. This physician examined, free of charge, a number of employees in one of the big saw factories for the purpose of discovering tuberculous workmen.

In 1909, the writer introduced the examination of employees in the concern of Sears, Roebuck & Co., of Chicago. The inception of this work was perfectly natural—an employee, with an injured hand, reported to the doctor's office during the second week of my work with this plant. While dressing the injury it was noticed that the general appearance of this employee was bad; examination was made, and an advanced stage of tuberculosis discovered. This led to an examination of the fellow-employees working in close contact with this man. Three other cases of tuberculosis were discovered in his department within a short time, and the adoption of a thorough examination of the employees naturally followed. It soon became evident that such examination would reveal many other diseases, which, taken in their incipiency, could be checked. From this fact arguments with the strongest economic basis were easily advanced in favor of all physical examination of all employees. Similar reports, setting forth the benefits of this practice, were made about the same time by Dr. Irving Clark of the Norton Grinding Co., of Worcester, Mass.; by Dr. Otto Geier of the Cincinnati Milling Machine Co.; by Dr. Wilbur Post of the People's Gas Co., of Chicago; by Dr. C. G. Farnum of the Avery Co., Peoria, Ill.; by Dr. S. M. McCurdy of the Youngstown Sheet and Tube Co.; by Dr. Lowe of the Goodrich Rubber Co., and by other workers in this field. By 1914, physical examinations of employees were a fixture in many industries.

The Committee on Factories of the Chicago Tuberculosis Institute, composed of Drs. James Britton, Theodore Sachs and Henry Faville, was instrumental in extending this system to a number of the

other industries of Chicago. Their report on this work, presented before the National Tuberculosis Association in 1914, gave a marked impetus to this branch of industrial medicine throughout the country. Since then the National Tuberculosis Association has been a staunch advocate of this form of medical work.

The studies of Dr. Thomas Crowder on ventilation, of Dr. Alice Hamilton on lead poisoning, of Dr. J. W. Schereschewsky and of Dr. George Price on health conditions among garment workers, and of men like Dr. E. R. Hayhurst and Dr. Francis Patterson working in connection with the Departments of Industry and Labor of the states of Ohio and Pennsylvania, respectively, stand out as milestones in the advancement of industrial health in this country, especially during the years 1910 to 1915.

In Milwaukee, Wis., during the week of September 30, 1912, there was organized the first National Safety Congress ever held in the United States. The birth of this great organization was due to the joint action of the Association of Iron and Steel Electrical Engineers and the Coöperative Safety Congress, and was given the name of National Council for Industrial Safety. The purpose of this organization was to devote every effort to the promotion of safety to human life in the industries in the United States. As its scope of activities broadened, the association changed its name in 1914 to *National Safety Council.*

Every physician and surgeon in the land, and especially those engaged in industrial practice, should be familiar with the history of this great National Safety Council. It has been the means of conserving thousands and thousands of lives. It has stimulated the medical profession to greater efforts in prevention. "Safety First" has become the twin brother of preventive surgery. Such physicians as Geier, Patterson, A. M. Harvey, Farnum, McCurdy, Lauffer, and L. A. Shoudy, early took a very active part in this new safety organization. Within the next two years many other surgeons in industry joined this movement. As a result, the *Health Service Section of the National Safety Council* was organized during the annual meeting of the Council in Chicago in 1914.

During this same period the surgical care of injured employees was advancing, due to the studies and contributions of such emergency surgeons as Moorhead, Clark, Farnum, Corwin, Harvey, Lauffer, Shoudy, Cotton, Bloodgood, Edward Martin, Lounsbury, Warnshius, Mock and others interested in industrial surgery.

In the American Public Health Association, Drs. W. A. Evans, E. T. Fisk, Alice Hamilton, E. R. Hayhurst, and B. S. Warren, with some fifty other physicians, recognizing the influence of this form of public health work formed the *Section on Industrial Hygiene* in that organization during the fall of 1914.

The year 1914 also witnessed the birth of the organization of the *Conference Board of Physicians in Industrial Practice,* under the secretaryship of Magnus Alexander. This organization was limited to the East, with headquarters in New York, and many of the leaders in industrial medicine and surgery were numbered among its members. Some of the greatest contributions to this specialty have been made by this group. During the same year reports emanated from the far West concerning the work being done toward improved conditions in our mining and lumbering industries. Such men as Dr. R. W. Corwin, Colorado, Drs. Tucker and Philip King Brown and R. T. Legge of California, Dr. Yokom of Washington, and a number of others, were responsible for these advances in the West.

For years the American Medical Association had frowned on the contract practices and other types of work of the company surgeon. The standard of this work in many instances had been far below par. But public recognition of this new specialty of industrial medicine was given in 1915 by this association. In the annual meeting of that year the Preventive Medicine Section of the American Medical Association (Dr. Otto P. Geier, chairman) had a symposium on industrial hygiene. Since then industrial medicine and surgery has had a place on every annual program of that section. In addition, last year the Orthopedic Section of the American Medical Association had a symposium on industrial surgery. The recognition of this work by the leading members of our profession testifies to the higher professional standard which it has attained.

At Detroit, Mich., in 1916, after a year of great effort on the part of twenty-five surgeons engaged in industrial practice in various sections of the country, there was organized the *American Association of Industrial Physicians and Surgeons*. The incorporation papers show 125 physicians and surgeons as charter members of this organization. Its aims have been to stimulate scientific study and research in all branches of industrial medicine, to stimulate industries to adopt a comprehensive health service, and to raise the standards of the physicians engaged in industrial practice. The combined efforts of this association have undoubtedly done more to increase the benefits from this work to both employees and employers than any other one agency which has entered this field. At present this organization has approximately 600 members.

In 1912, the United States Public Health Service formed its Division of Industrial Hygiene—now known as the *Division of Industrial Medicine and Hygiene*. For several years the work of this division was directed by Dr. J. W. Schereschewsky, now Assistant Surgeon General of the U. S. Public Health Service. More recently Dr. A. J. Lanza has been in charge of this division. Special investigations have been made in the garment, steel, various chemical industries, the grinding and cement industries, lead, coal, and copper mining, and a few others. The studies of this division have been responsible for establishing industrial hygiene in many diversified industries. This work has been greatly facilitated by the services of Dr. C. F. Rucker and Dr. B. S. Warren of the Public Health Service, and such consultants as David Edsall, George Price, Gilman Thompson, A. S. Stengel, C. D. Selby, Frederic S. Lee, Otto Geier, and many others.

The United States Department of Labor, within the last eight years, has rendered most valuable service to the country along various lines of industrial hygiene, through the work of Drs. Alice Hamilton, Royal Meeker, L. P. Cheney, Grace Meigs, and others. Exhaustive studies of this subject have been made, and the department's work on occupational diseases, accident hazards, fatigue, ventilation, lighting, child labor, hours of labor, and numerous other phases have formed a basis for correcting faulty conditions in many kinds of industry.

The Bureau of Mines has been engaged in a similar service in the mining industries of the country. These efforts of the national government to improve the hygienic conditions of the employees of the nation's industries are most praiseworthy. They mark the beginning of what must finally come to pass—a centralized supervision of health conditions throughout the country, not only among industrial employees but in all walks of life.

It is to be deplored that several federal departments are engaged simultaneously in this work of industrial hygiene. The desire to justify appropriations, to secure credit for doing a piece of work and the existence of certain inter-departmental jealousies which prevent proper co-operation between departments, all tend to duplication of effort and to retardation of results.

During the first three months following the nation's entrance into the war, many suggestions came to the government from the American Association of Industrial Physicians and Surgeons, the American Railway Surgeons' Association, the U. S. Public Health Service, and similar organizations, concerning the conservation of the industrial army for this great struggle. Most of these were referred to the Medical Section of the Council of National Defense. In October, 1917, Dr. Franklin Martin, Medical Director of the Council of National Defense, called a meeting of approximately fifty of the leading workers in the field of industrial medicine. As a result, there was organized an Advisory Committee on Industrial Medicine and Surgery, a sub-section of the Medical Section of the Council of National Defense. This committee proposed elaborate plans for the supervision of the health of all workers engaged in essential war occupations. Few of those in authority were familiar with this new field in medicine, and it took weeks and weeks of patient endeavor to sell the idea. On May 27, 1918, a committee was finally organized so as to include many diversified interests, a director was appointed, and a plan proposed which covered the scope of the work for the committee.

The following is a synopsis of this report, and shows how vital the program was

to the country's preparedness for war, and how more and more vital it would have become had the war continued longer:

INDUSTRIAL MEDICINE AND SURGERY AS A WAR MEASURE

Report of the Director: Dr. Otto P. Geier, May 27, 1918

The Need of the Hour—More production of war materials by the second line of defense.

Slowing Down of Industry Caused—

1. By excessive labor turn-over.
2. By physical breakdowns—
   a. Due to unsanitary conditions of shops and homes (lack of medical supervision).
   b. Due to lack of early recognition and prompt treatment of ailments leading to invalidism.
3. By absence from work—
   a. Due to preventable accidents.
   b. Due to lack of immediate medical and surgical care.
4. By lack of output because of those killed or permanently disabled.

Production Can be Definitely Speeded up by Protection of the Human Machinery from Preventable and Unnecessary Wear and Tear, Disease and Injury.

The non-effectives in the average industry are known to be at least 3 per cent., or thirty in each thousand, on account of sickness (study of 750,000 workers, U.S.P.H.S.: may go as high in others as 6 per cent. of non-effectives). Add to this factor an additional 2.5 per cent. for absence, falsely claimed to be due to sickness; then add 0.5 per cent. for absence on account of lost time due to accidents and we have a total absence of 6 per cent. to which medical men can direct their efforts.

The *principles* of *industrial medicine* and *surgery* intelligently applied can reduce this 6 per cent. to 3 per cent., making a gain of 30 workers on the job in every 1000.

Additional Saving—A cleaner plant and healthier workmen will result in a greater output per man.

Other By-Products—Better relations between employer and employee—more sympathetic understanding—comforts and conveniences, cafeterias, etc., supplied; all producing a better *esprit de corps* resulting in less labor turn-over.

The protection of the health of the community—women and children—quite as essential as the health of the workers. Fully 30 per cent. of the effective medical and surgical capacity of the profession has been drawn into the army. Twenty-four per cent. of the visiting hospital forces have been called into the service. This indicates that the civil population does not possess adequate medical service. Under strain of war conditions, disease and injury are increased. To meet this discrepancy, a method must be found by which every physician not in the army may give his maximum result with his minimum effort, so that the community may be adequately protected against disease.

The placing of the physician in industry accomplishes that need. Applying his preventive measures to the large industrial unit on an intensive scale, the industrial physician assists the community in its health efforts, lessens disease and therefore lessens the strain on the physicians in private practice.

Our Problem, Therefore, Is:

1. To meet the military need for greatly increased production.
2. To offset the drain on the man power in industry brought about by raising the military forces.
3. To assure adequate medical service for the civil population.

To Meet the Problem, the Government Must

1. Provide against unnecessary human waste in industry and society during the war.
2. Increase output by maintaining workers in good health.
3. Avoid preventable deaths and disabilities from accident and disease.
4. Restore to full producing power in the shortest possible time sick and injured workers.
5. Provide healthful places in which to work.
6. Provide healthful homes and communities in which to live.

Methods of Accomplishment:

Through the influence of the Advisory Committee and through the efforts of the Director, we should secure:

1. *Centralization and coördination*, with stimulation of all present agencies (federal, state and local).
2. *Enlistment and coöperation of the Public, of Industry and of Labor:* By a well organized educational campaign.
3. *Establishment of Standards.*
   a. Preparation and distribution of standards to cover the field of "Industrial Medicine and Surgery," emphasizing the occupational diseases of war industries.
   b. Establishment of minimum standards of plant dispensaries and medical personnel.
   c. Adoption of standard forms for use by industries in record of accidents and disease. (These records will be the basis for the first reliable and uniform statistics on morbidity and accident.)
4. *Personal Contacts.*
   a. Addresses before manufacturing and trade organizations—national associations, medical and social.
5. *Field Work* (Most important of all the measures.)
   a. Surveys of large industries engaged in war work by expert field workers, with recommendation to industries inspected. Copies of reports to go to that branch of the War Department interested in the output of that particular industry.
   b. Study of community sanitation to determine its responsibility toward the workers' health.
6. *Schools of Industrial Medicine and Surgery.*
   a. Propaganda to popularize courses of study for the specialty of industrial medicine and surgery in existing colleges.
7. *Legislation.*
   Study of industrial hygiene legislation of the several states for purposes of recommendation and standardization.

Personnel of Organization.

A Director (whose relationship to the committee shall be that of a president to his board of directors).

An Executive Secretary with industrial training and ability.

A Staff of Technical Advisors.

A Staff of Field workers—Present industrial force of P. H. S. greatly enlarged, and such additional men as our funds will permit.

A Staff of Speakers—volunteers.

The Advisory Committee on Industrial Medicine and Surgery.

Signed by the Committee:

Public Health Service, Dr. Joseph Schereschewsky, chairman.

Department of Agriculture, Dr. Carl L. Alsberg.

Department of the Interior, Mr. Van H. Manning.

Department of Commerce, Dr. W. A. Davis.

Department of Labor, Mr. Royal Meeker.

Organized Industry, Mr. Magnus Alexander.

Organized Labor, Mr. J. W. Sullivan.

Organized Medicine, Col. Charles H. Mayo.

Organized Industrial Medicine and the Army, Lt.-Col. Harry E. Mock.

Dr. Franklin Martin and Dr. F. F. Simpson, ex-officio.

By the efforts of a few members of this committee many of the above proposed projects were adopted by various governmental agencies. It was apparent from the start that no great progress could be made until this entire program, as well as other public health measures, were centralized under one agency. On July 1, 1918, the President issued an executive order, under the powers given him to coördinate the work of various departments, which stated that "All sanitary or public health activities carried on by any executive bureau, agency, or office, specially created for or concerned in the prosecution of the existing war, shall be exercised under the supervision and control of the Secretary of the Treasury." The only exception to this was the work of the medical departments of the Army and Navy. The order designated the U. S. Public Health Service as the bureau of the Treasury Department responsible for this work.

While the Public Health Service did not boldly take over every health agency of the government as prescribed in the above executive order, yet under this power they were able to extend the scope of their work, and to coördinate more closely with many of these agencies. The executive order was a step in the right direction, and if the war had continued would undoubtedly have led to great advances in public health, even to a national health administration.

Early in 1918, the Department of Labor underwent a reorganization. Its War Labor Administration Bureau took charge of the labor supply of the country, dealing it out and shifting it according to priority importance. This bureau interested itself in many of the health problems connected with labor. It coöperated with many of the state Departments of Industry and Labor, the State Council of National Defense, especially the Women's Division of the same, and many other organizations.

A Women's Division of the Department of Labor was organized under the direction of Miss Mary Van Kleeck. A committee representing the Office of the Surgeon General of the Army, the Ordnance Department, the Navy, the U. S. Public Health Service, the National Research Bureau, the War Industries Board, and other divisions of the Department of Labor, was formed in June, 1918, to act as the steering committee for the Women's Division. This committee made a thorough study of the occupational hazards for women workers in several specific industries. Many improvements in the working conditions of women were the results of this committee's activities.

The Ordnance Department organized a Division of Sanitation and Safety; the Railroad Administration formed its Safety Department; the Shipbuilding Board organized its Department of Medicine and Surgery, and other departments of the government were beginning to apply the principles of industrial medicine and surgery to their working forces before the signing of the armistice.

We have a few examples of an active interest on the part of state governments in industrial health conditions, but these are the first examples of an active, constructive federal program for introducing industrial hygiene into specific industries.

The great importance of this step may not be fully appreciated by many. But to those surgeons in industry who have devoted many years of their lives to establishing these principles, and to their lay allies, who have so thoroughly supported and abetted their efforts, the dawn of a new day has come; never again will we return to those dark ages when the human machine was worked to the limit without supervision and then prematurely scrapped because of a breakdown, often the direct result of the occupation.

During the last five years medical schools, recognizing the great opportunity for service offered to physicians in this field, have instituted courses covering some phase of the problem. Before the war Rush Medical College, Cornell University, the University of Pennsylvania, the University of California, and the University

of Ohio, were practically the only schools teaching some branch of industrial medicine. To-day at least six medical colleges are teaching some phase of this subject, and I know of four others contemplating the introduction of courses next fall.

The physicians and other workers in industrial hygiene cannot claim full credit for the developments in this field. A few large corporations, without the help or advice of medical men, voluntarily adopted improvements in the working conditions of their employees. A pioneer in this great effort was the National Cash Register Co., of Dayton, Ohio. The Norton Grinding Co., the Cincinnati Milling Machine Co., the Ford Motor Co., the International Harvester Co., the Avery Co., Crane & Co., the American Telephone & Telegraph Co., Sears, Roebuck & Co., and a few other large corporations were among the pioneer institutions which installed departments, including most of the principles embodied in a real human maintenance program.

As a result of these combined efforts of individuals, organizations, and certain employers on the one hand, and of the various state and federal agencies on the other, we are able to point to approximately 8,000,000 of the workers of the nation who are receiving, to a more or less degree, the benefits of this enlightened era in industry. But there still remain about 30,000,000 of our people who are responsible for production of some type in this country who are receiving no kind of health supervision. Many of these people are working under intolerable conditions. The amount of child labor still in use is unbelievable. The lack of protection against the commonest forms of occupational diseases is appalling.

Even in many of those concerns where maximum production was so essential for the winning of the war, inadequate housing conditions, unsanitary factory conditions, prevalence of occupational diseases, and a high accident rate, due to speeding-up and to green employees, were tolerated —inexcusable inefficiency at such a time. The labor turn-over in some of these concerns was over 500 per cent. To counteract this labor turn-over higher and still higher wages were paid—often defeating its purpose by increasing the turn-over. Even patriotism cannot overcome the bad influence on the working man of such intolerable conditions.

Each month of the war witnessed an improvement in many of these concerns. If the same forces which were so indefatigable in their efforts for conserving the health and efficiency of the industrial army during the war will only carry over these efforts into the reconstruction period, an entirely new standard of existence will result for the working people of the land, the great army who must produce and provide.

Thus, in the course of one short decade, broad humanizing principles combined with scientific medical and surgical work have permanently established in the medical profession this far-reaching health service—Industrial Medicine and Surgery.

LEAD POISONING IN AMERICAN INDUSTRY*

ALICE HAMILTON, M.D.

Special Investigator, Department of Labor, and Assistant Professor of Industrial Medicine, Harvard Medical School

THE subject of industrial lead poisoning is so large that if it is to be compressed into one lecture it must be limited in some way, and I have decided to take as my field to-day only the contributions which have been made by Americans to the theoretical and practical aspects of industrial plumbism. The foreign literature is easily available to you, while a great deal of the American is tucked away in government reports and rather obscure medical journals. While much that is found in European literature is applicable to American conditions, not all of it is. There are several trades which are notorious sources of lead poisoning in European countries but which here are carried on in a different way and do not give rise to lead poisoning. For instance, cheap tin-

*Cutter Lecture in Preventive Medicine and Hygiene, delivered at the Harvard Medical School, April 2, 1919. Received for publication March 3, 1919.

ware seems to be made in Great Britain and Germany with a lead and tin plating while ours is made either of galvanized iron or of ironware covered with an excessively thin coating of pure tin.

Dyeing and calico printing are always listed among the lead trades in Great Britain, but Edsall (1) found no evidence of lead poisoning from this source in the great textile district of Philadelphia, Kensington. In the Episcopal Hospital in the center of this mill town there had been no case of plumbism in a woman in five years, though thousands of them work in the mills. Among ninety-eight industrial cases in men only one was a weaver and he had probably not contracted the poison from his work. The only case of poisoning from lead-dyed textiles that I have heard of in this country was sent me by Dr. D. J. M. Miller of Atlantic City. He saw a woman with profound neuro-retinitis as one symptom of a bad case of lead poisoning, and her father also had typical lead poisoning though without eye involvement. The woman tore old window shades into strips and wound the rags into balls, and her father wove them into rag rugs.

File making by hand seems to be very common in Europe and the literature on lead palsy is full of descriptions of the peculiar form that is found among file makers. Files in this country are made mostly by machinery, though Hayhurst reports three cases of lead poisoning in file cutters, men who were also doing lead tempering. Diamond polishing is either not carried on to any great extent in this country or is not done in the same way as it is in Holland, for while this is a notorious lead trade in that country, there seems to be but one instance of lead poisoning in a diamond polisher in our literature. E. E. Pratt (2) reports one case discovered during the study made by the New York State Factory Investigation Commission.

There are two great advantages which America has over European countries; we do not employ women in the dangerous lead trades nor do we employ many immature boys and girls. On the other hand, there are several lead industries which are attended with greater danger in this country than in European countries because of American methods.

The following is a very brief statement about the most important lead industries in the United States, with special emphasis on the features peculiar to this country.

Lead mining is carried on chiefly in southeastern Missouri, in Utah, Idaho, and Montana. The Missouri ore is practically pure galena, lead sulphide, but the western ores are nearer the surface and oxidized ores are still mined to a certain extent. These compounds are, of course, more soluble than the sulphide and lead poisoning has always been present in these mines, although as the surface ores become exhausted and the deeper sulphide is mined, it tends to disappear. St. Vincent's Hospital in Leadville has records running back to 1880, and for some time the miners treated in the hospital for lead poisoning numbered about forty to fifty a year, but by 1910 the cases had fallen to eight, and in 1912 there were none at all (3).

Even galena mining is apparently not free from danger. Louis (4) in Oliver's *Dangerous Trades,* says that among 16,827 British lead miners handling sulphide ore only, lead poisoning was practically unknown, only one death having occurred. But one cannot prove the point by saying that there were no deaths. Industrial lead poisoning is seldom fatal. When we were searching in the St. Louis hospitals for cases of lead poisoning from the great smelters nearby, we found records of twenty-five cases which had been treated in the Alexian Brothers Hospital, all of which had come from the lead belt, chiefly from Desloge. They were not from the smelters—there is only one small smelter there—but from the mines and concentrating mills. All were serious enough to require hospital care. One had palsy and another a lead psychosis. These men were handling pure lead sulphide ore and in general this compound has been assumed to be non-poisonous and the statement is commonly made in the literature that this is the one insoluble form of lead. Blum was the chief authority for this assertion and his dictum was generally accepted, though Murgia and Brezina and Eugling got results that pointed to absorption of lead sulphide in the body.

It may be interesting to know that there was a controversy on this subject in 1906 in Milan, at the International Congress of

Industrial Hygiene. Rambousek insisted that lead sulphide was harmless as shown by the fact that there had not been one case of poisoning among 10,000 Bohemian miners. On the other hand, Biondi had seen lead poisoning among the lead miners in Sardinia. The point was finally settled by A. J. Carlson and A. Woelfel (5) of the Physiological Department of the University of Chicago. They tested, with human gastric juice, sulphide ores from the lead belt of Missouri and pure laboratory lead sulphide and found the average percentages of lead dissolved to be, for the pure sulphide, 4.6 per cent.; for the ores from three districts, 1.38 per cent., 2.94 per cent., and 3.32 per cent.

Lead smelting and refining is a very important industry in the United States where much bullion from Mexico is refined in addition to the smelting and refining of our own ores. In 1912, the twenty principal plants employed some 7500 men but this did not include a large smelter on the Pacific coast nor the great number of small refineries working up lead scrap and junk that are to be found in practically every city in the country. The chief centers of the industry are Perth Amboy and Newark, N. J.; Graselli and East Chicago, Ind.; Federal, Granite City, and Collinsville, Ill.; Herculaneum and Joplin, Mo.; Omaha, Neb.; Denver, Leadville, Pueblo and Salida, Col.; Murray, Midvale, and Tooele, Utah; and East Helena, Mont.

American smelting plants are in many respects modern in construction, contain many mechanical devices to do away with hand labor, and an effort has been made in all of them to remove the lead fumes which constitute the great danger in lead smelting. They are, however, far from being model plants though they have improved since 1912 when their rate of lead poisoning was very high. I doubt whether even now any of them would compare with the German smelter I visited in 1912, which was under the direction of a great authority on lead poisoning, Richard Mueller. He had constructed this smelter in such a way as to be able to depend entirely on artificial ventilation, which means that all of the departments, even the tapping floor of the blast furnace, were indoors. Of course, when one or two sides of the building are left open, as is customary in our smelters, the ventilation, or rather the removal of fumes, is at the mercy of wind and weather.

Refineries are probably more productive of lead poisoning than smelters though the heat required in the furnaces is not so great and therefore the fume evil should be less. But refineries work up a great deal of dusty scrap and dross and they are likely to be neglected places, carelessly managed, and cheaply run. The cases of lead poisoning in both branches in 1912 numbered 1667 cases in nineteen plants employing 7400 men, which is a little over twenty-two for every 100 employed. The British rate for that year was only 1.8 per hundred; four German smelters had between 10 and 11 per 100, and one large Austrian plant had 9 per 100 (3).

The metallic lead trades are very extensive, employing large numbers of men and almost all the women who come in contact with lead in industry. There are so many industries in this class that it would be impossible to give anything like a complete list. I have selected those occupations in which industrial lead poisoning has been known to occur in the United States, sometimes in quite serious form:

Lead burning.
Making solder and babbitt.
Soldering.
Making lead pipe, sheet, wire, machine parts, plumbers' goods.
Making shot.
Lead tempering of machine parts.
Making and laying electric cables.
Making leaden trimmings for coffins.
Making leaden picture frames.
Making and using tin foil.
Making car seals and can seals.
Brass founding.
Brass and nickel buffing.
Tinsmithing.
Plumbers' trade.
Typographical trades.

We usually think that handling metallic lead is one of the least dangerous kinds of lead work for the only soluble part of the lead is a fine greyish coating of oxide that forms on the surface and can be rubbed off. Still there are cases on record of lead poisoning following only a short employment in such work. Pratt (2) tells of a twenty-two-year-old man who was poisoned by unloading pig lead from

barges. In a Chicago hospital a man was treated who had for two months swept up the shavings from the casting and finishing machines in a factory where lead fixtures were made. An even more unusual case was found in a Philadelphia hospital. This man suffered with acute lead poisoning after only three weeks' work making lead stoppers and perforated filters for wash basins. Brass filers and polishers not infrequently get lead poisoning from the small amount of lead present in the alloy, this being of course metallic lead, and I have known plumbism in a sorter of lead and brass junk, and in a man who swept up dross from around a kettle and carted it away.

The plumbers' trade is gradually becoming much safer but lead is still used and lead poisoning still occurs among plumbers. Nineteen of the 560 cases found in Illinois were in plumbers. Lead burning is well known to be attended with a great deal of lead poisoning. This is because the lead burner usually has to work inside the receptacle which he is burning. He has to climb into the tank he is lining or put his head into the box. There is another form of so-called lead burning that really should be classed as soldering and that does not require so much skill nor involve nearly as much danger. The men who burn lead connectors in storage battery manufacture use a tiny flame to melt a bar of solder and get very little lead fumes.

Two occupations which do not seem to be conspicuously bad in Europe, judging from the literature, give rise to a great deal of lead poisoning in this country. One of these is soldering cans. This causes an amount of lead poisoning quite disproportioned to its real danger. At present the records of most hospitals in our large cities contain more cases of plumbism among the users of solder and babbitt than among workers in such notoriously dangerous industries as white and red lead, paint grinding and making storage batteries. The Illinois Factory Inspector's Report for the year 1913-1914 contains 184 cases of lead poisoning from four places in which tin cans were soldered. In one crowded workroom with twelve unhooded soldering machines, there were 100 persons employed and here eighteen cases of lead poisoning developed during one month of cold weather when the windows were closed. Another industry in Illinois has a disproportionate amount of lead poisoning. This is the casting and finishing of leaden car seals. There were twenty-eight cases of lead poisoning in a force of 188 employees in Chicago, in one year. E. E. Pratt describes a process which I have never seen mentioned in foreign literature, lead tempering of magnetos, piano wires, and wire cloth. The objects are heated, then plunged into a trough of molten lead, taken out and cooled rapidly, and then rubbed smooth with sand paper. The combination of fumes and dust renders this occupation very dangerous and Pratt found nine cases of lead poisoning in one magneto factory with an average force in that department of only nine men. Kenney (6) of New York describes a case in a temperer of magnetos who was incapacitated after eighteen months' work, with wrist drop, general weakness, colic, anemia, and loss of 50 pounds weight.

The printers' trade needs special mention among those in which metallic lead is used. Probably more study has been devoted to the health of printers in all countries than of any other class of men, for they are decidedly above the average of working men in intelligence and they have not only noted their own high sickness and death rate, but have insisted on finding out the cause of it. You will find very detailed studies of the typographical trades in the literature of Germany, Austria, Holland, and Italy; the English and French are less full. Certain disadvantages in the printers' trade in Europe become evident in these foreign reports, when one compares them with conditions here. There is a very large proportion of youthful workers, especially in Holland. The Germans, Austrians, and French say that the industry attracts the underdeveloped, sickly boys and that printers are far below par physically. Pannwitz found that there was a startlingly small number of printers fit for military service in Germany. In fifty-five districts the average of the physically fit was 427 out of 1000, while the typographical trades had only 238. American printers are certainly not so greatly handicapped as this, though the records of the Prudential Life Insurance Company show that

they average a little lower in inches and a little lighter in pounds. The figures are: 149 pounds for printers, 157 pounds for occupied males; 67.7 inches for printers, 68.1 inches for occupied males.

The Typographical Union has interesting records of the mortality of American printers from tuberculosis and the so-called degenerative diseases, but little or no information as to lead poisoning. To throw light on its prevalence an examination of 100 printers was made in Chicago by Dr. J. D. Ellis, and a similar examination by Dr. Walter W. Palmer in Boston. They found eighteen cases of plumbism among these 200 men, or 9 per cent. However, only ninety-three, 46.5 per cent., were found to be free from noteworthy symptoms of ill health; the remaining 107 had health more or less impaired. The significant symptoms were abdominal pain, constipation, articular pains and headache (7).

Conditions in the printing trades have improved greatly of late years and are now, on the whole, fair, sometimes excellent. The model printing establishment, however, in my experience, is still the Royal Printing Shop at The Hague, where the bright red tiles of the floor are kept free from any particles of lead, the benches are spotless and all lead pots are hooded.

The manufacture of white lead has been regarded in every land as one of the most dangerous of the lead trades, if not the most dangerous. In the United States it was even more dangerous than in Europe. In the making of white lead, dust is the great danger and our methods are much dustier than those of England or Germany. I am sure you are familiar with the Old Dutch process of making white lead. This same process is used in England, Germany, and Belgium, but it is only in Belgium that the corroded lead is separated from the uncorroded remnants by a dry process as it is here. In England and in Germany the pots of corroded lead must not even be emptied till the whole has been sprinkled with water to keep down the dust; then the corroded lead is thrown into tanks of running water and the white lead is washed off and flows along leaving the uncorroded cores of metallic lead behind. In our white-lead works, the pots must be emptied without sprinkling and the corroded lead is carried to a dry separator from which the white-lead powder and cores are discharged in a dry state. Obviously there is a great deal more danger in this way of handling white lead.

Another feature peculiar to the American white-lead industry is the Carter process of corrosion. This is a quick corrosion of lead which has been atomized to the finest powder so that acetic acid can act rapidly upon it. The disadvantage of the method is that it involves the handling of powder throughout. The advantage is that it is largely mechanical, requiring little handwork.

Since 1910, when this industry was investigated, very far-reaching improvements have been made, especially in the white-lead branch and the rate of poisoning, which then was 388 cases in sixteen months in a force of 1600 men, is now very much lower (8). The centers for the manufacture of red and white lead are: Brooklyn, Perth Amboy, Philadelphia (the largest), the region near Pittsburgh, Cincinnati, Detroit, St. Louis, Chicago, Joplin, Omaha, and Selby, Cal. In one plant only, the one at Joplin, roasting oxides is carried on in connection with lead smelting as it is in Europe. Our usual way is to combine oxide roasting with corrosion of white lead.

Lead poisoning in potteries and tile works was notorious for years in England and Germany, and in both countries, especially the former, great efforts have been made to protect potters and tile workers against the lead used in glazing and decorating. The results have been quite wonderful and English potteries are, on the whole, the most remarkable instances of factory sanitation I have ever seen. Aside from the precautions taken to avoid dust and other dangers, the English make an effort to render the lead in their glazes insoluble by fritting it; that is, by fusing it with the other constituents and thus changing the soluble white lead, or the lead oxide, in part, to the insoluble disilicate. This is not done in our potteries. The glaze is fritted but most or all of the lead is added after the fritting. Unfortunately this far more poisonous American glaze is used in potteries which do not in any respect bear comparison with British and German potteries and there is much more lead poisoning among the men and women

potters in America than in Europe, just ten times as much among a group of men dippers in Ohio as among the dippers in North Staffordshire. The chief centers of these industries in this country are Trenton, the East Liverpool region and the region around Zanesville, both in Ohio (9).

Enamelling sanitary ware is a much more important industry with us than with Europeans. We build more new houses and we put a great many more enamelled bath tubs and sinks into those houses. But the fact that this is such an important industry in America has not led us to take better care of the workmen than the English and the Germans do of their far smaller number. Quite the contrary is true. The great majority of British and German enamelware factories use a leadless enamel and in Germany the enamel is applied with water. Only in Austria is enamelling done as it is here with a dry glaze, rich in red lead, applied in powder form over red-hot ware. In Austria this is known to be a very dangerous lead trade. Our enamellers and enamel grinders work in an atmosphere thick with glaze dust that contains from 2.5 to 20.4 per cent. of soluble lead. It is one of our very worst lead trades.

In enamelling sanitary ware and sinks the rate of plumbism in 1911 among something over 1000 men was 21.4 per cent., but an examination of 148 men out on strike showed that 36 per cent. were affected by the lead. Whether or not the industry has improved of late years I do not know. The largest center for this manufacture is Pittsburgh, with three neighboring towns, and there are also plants in Trenton, Louisville, Chicago, Chattanooga, and Sheboygan, Wisconsin.

For many years there has been an agitation in Europe in favor of the substitution of zinc white for white lead in paints because of the recognized danger of white-lead paint. No country has gone so far as to prohibit altogether the use of lead paints except France, in which country the law prohibiting the manufacture or importation of white lead and of white-lead paint was intended to come into force January 1, 1915, but probably the war postponed this date. In Germany the law protects the painter against lead dust by forbidding him to mix white lead by hand or to use dry rubbing down for painted surfaces. It also requires the contractor to make very generous provision for the cleanliness of the painters. In Belgium, dry rubbing of lead paint is forbidden, and washing facilities and lunchrooms required. These same features are covered by the Austrian law, which also requires the labeling of paints to show which contain lead, and discourages the use of lead paints for interior work. Scandinavian and Swiss painters tell us that in their home countries zinc white is used for interior work far more than it is here in America, and it is customary to dip sand paper in oil before using it to rub down. Evidently then there is more risk of lead poisoning for American painters than for European.

The most dangerous branches of the painters' trade in this country are ship painting, interior decorating, especially expensive work—for cheap houses are likely to be painted with quick drying leadless paints—and certain departments of carriage and automobile painting. All these require rubbing down and exposure to fine lead dust. There used to be a great deal of poisoning among men who painted the interior of Pullman cars, but now a sublimed lead paint is used, which is less poisonous than white lead.

Painting is, of course, the most notorious of the lead trades and in almost every hospital and dispensary painters make up the large majority of the cases of lead poisoning. This is partly because every community has some painters and may have no other lead workers, partly because it is a skilled trade and men do not drop out if they can help it, and partly because lead poisoning in a painter is more likely to be recognized by the physician than is the case with other lead workers. Of sixty deaths from plumbism in New York State, reported in 1910 by Andrews, 75 per cent. were painters. Thirty-eight per cent. of the 109 serious cases described by Pratt in New York City in 1911 were painters, and 26 per cent. of the 578 cases of plumbism found in Illinois in 1908-1910. These figures show that if you take all the cases of plumbism in a community you get a large proportion of painters among them; if you pick out the most serious cases, the proportion increases; while if you take the deaths only, the proportion of painters becomes enormous.

The form lead poisoning takes in painters is consequently very severe. Of 100 lead-poisoned painters in the County Hospital in Chicago, two-thirds had had more than one attack and only one-third had the pure gastric form of plumbism without complications. There were 39 cases of palsy, 6 of acute encephalopathy and 3 of slow mental deterioration, 11 of disturbed vision, 24 with arthralgia, and 8 with arteriosclerosis of marked degree.

Several interesting studies have been made of groups of painters in this country. Hayhurst (10) examined 100 working painters in Chicago in 1913. He did not find any with acute symptoms of lead, but indications of chronic plumbism were found in seventy cases. In 1915 Apfelbach and Gibson of the State Factory Inspection Department of Illinois examined 150 painters and noted that twenty-three had a history of lead colic, while diseases in which lead may have had a part were found as follows: 22 nephritis, 49 hypertrophied heart, 9 of them with valvular disease, 26 active tuberculosis, and 10 with latent tuberculosis. In 1918 Harris of the Occupational Disease Clinic of New York City Health Department, published the results of an examination of 304 painters, 162 of whom, or 53 per cent., had symptoms of plumbism and seventy-five gave definite reaction for lead in the urine.

Another American contribution to the study of the painters' trade was made by Dr. A. J. Carlson (11) on the comparative solubility of white lead (basic carbonate) and lead sulphate, called in the trade, sublimed lead. The controversy that led up to this investigation was not scientific but commercial, the Pullman Company having announced its intention of substituting lead sulphate for white lead and giving as one reason the non-poisonous qualities of the former. Very extravagant claims as to the safety of sublimed lead paint were made by the manufacturers both here and in England and it seemed necessary to put them to the test. Using the human gastric juice, of which Dr. Carlson has a never-failing supply from a man with gastric fistula, he found that lead sulphate, if dissolved in gastric juice is soluble to the extent of 24.7 to 30 per cent., while the basic carbonate is soluble to the extent of 59.8 to 77.9 per cent. This shows that though lead sulphate paint is less harmful than white-lead paint, it is far from being harmless.

Storage battery manufacture is carried on in six large plants in this country, in Philadelphia, Niagara Falls, Depew, N. Y., Cleveland, and Indianapolis. They were investigated in 1914 and again in 1918, and not nearly as much improvement had been made in those four years as one would expect. As carried on in this country storage battery manufacture is a very dangerous lead trade, having in 1914 a plumbism rate of 17.9 per cent. while Great Britain's rate was 2 per cent. in 1912 and the largest plant in Germany had 0.97 per cent. Only one of our plants is scrupulously clean and carefully managed, though three more are fair (12).

The use of lead in the rubber industry must be mentioned, though this is not really a lead trade, only a few rubber workers being exposed to lead. Litharge and lead sulphate are the salts used in compounding, rarely white lead. Most of the information on lead poisoning in the rubber industry comes from Ohio and Massachusetts, but New Jersey is also a very important rubber state. The dangers are easily controllable and although lead poisoning is not at all notorious in rubber works, still it is surprisingly common in some plants. In one, employing 1200 persons, only twenty-five handle lead, but there were in one year four cases in the compounding room and seven at the mixing mills. Another large factory with forty-four men compounding and bolting, had fifteen cases in one year (13). Among 162 cases of lead poisoning in the Massachusetts General Hospital, eighteen or 11 per cent. were rubber workers.

It would be impossible to give a list of all the occupations in which lead constitutes a hazard in American industry. W. Gilman Thompson gives eighty-five and several of them are not occupations but trades with several processes, differing much in danger. Hayhurst points out the importance of specifying not only the trade, but also the process in which the worker is engaged. He has found lead poisoning in an oil refinery, from handling lead pipe; in making scientific instruments, from grinding and soldering parts; in making emery wheels, from the use of babbitt.

These are a few of the more unusual sources of lead poisoning gathered from the lists of Thompson (14), Kenney (6) in New York, Hayhurst (15) in Ohio, and the Illinois Occupational Disease Survey: using white lead in white felt hat manufacture; drawing bristles through the pads of brushes, which have been painted with white lead; stenciling patterns with white lead; lineoleum manufacture, litharge being added as a drier to boiling oil and lead colors being applied; carrying leaded torpedoes in the same pocket with chewing tobacco; tempering parts for cash register machines; polishing cut glass with putty powder; zinc smelting; making artificial flowers; making and selling wall paper; making sodium acetate from the wash water from white-lead works; placing enamelled letters on windows with a white-lead paste.

PORTAL OF ENTRANCE FOR LEAD

Of the three portals of entry, the skin is probably negligible if we are considering industrial poisoning only. At least that is the opinion of the best British and German authorities and I have found nothing in American literature to contradict it. The intestinal tract is by far the most important but this does not mean that most cases of lead poisoning are caused by eating food or chewing tobacco that has been contaminated with lead. The breathing in of lead dust and fumes is by far the most frequent cause of lead poisoning, but most of the lead that is breathed in is not absorbed through the lungs but through the intestinal tract. K. B. Lehmann's assistants, especially Saito (16), have shown that when dust is inspired, less than one-quarter reaches the lungs; the remainder is caught in the mucus and saliva and is swallowed. So the mechanism of poisoning from fumes and dust is practically the same as that from eating soiled food, and it is incomparably more frequent.

Perhaps the most common superstition with regard to industrial plumbism is this, that the lead worker poisons himself by neglecting to wash his hands and scrub his nails before he handles his food. Certainly this is a possible source of poisoning, but any one who stops to think for a moment can see that it could rarely give rise to anything but a slow and gradual form of plumbism. Richard Mueller, the head of a model lead smelter in Germany, succeeded in estimating the amount of lead which a man might breathe in and compared it with the amount that could be washed off his hands at the end of a day's work. He found that a blast furnace tapper could breathe as much as 1.0625 gm. in the course of a ten-hour day, but that it was possible to wash off his hands only 0.0876 gm. (17). Obviously unless a worker literally washed his hands in his soup or coffee, he could not get even all of that into his mouth.

Even if the man works with large quantities of fairly soluble salts of lead, I doubt if the danger of his getting the lead into his mouth from his fingers is as great as the danger of breathing lead dust. Occasionally one does come across a case of real finger poisoning. In the Cook County Hospital a Bulgarian was treated for acute lead poisoning which, he said, he had contracted while pasting plates with litharge paste in a storage battery plant. He did not know there was any harm in the mixture and so he used to moisten his fingers in his mouth. He was seriously sick at the end of ten days. Another occupation in which poisoning takes place by direct ingestion of the lead is the work of commercial artists, mechanical re-touchers, who touch up the photographs for catalogues and advertisements with white paint in order to bring out the high lights. They often put their little paint brushes in their mouths and as they almost invariably use white-lead paint, serious forms of poisoning are found among them. We discovered fifteen cases in Chicago in 1909.

But such instances are exceptional. As a general thing a man does not put his fingers in his mouth, he eats only three times a day, but he breathes all the time. A few years ago I had an opportunity to compare two typical lead trades, one wet and one dusty. Eighty-six white-ware dippers worked with their hands and arms covered with a liquid glaze that contained from 10 to 20 per cent of soluble lead. One hundred and forty-eight sanitary ware enamellers scattered a finely ground enamel over heated iron ware, the dust containing only 2.5 to 9 per cent. soluble lead. One dipper in every six to seven had lead poisoning, but one enameller in every two to three (9).

It has seemed important to lay stress on this point because it is one on which industrial physicians are so very likely to be at fault. I remember a physician in charge of a large smelter who told me that the lead poisoning among the men was attributable to their dirty habits and that he was continually urging them to scrub their nails. I had just been out to the smelter and had seen the discharging of a great Huntington-Heberlein pot containing tons of roasted ore, red-hot and fuming. It fell with a great crash on the grating of the dump and when the clouds of dust and smoke cleared away a little, I could see the men chopping the bigger blocks and pushing them through the grating. These were the men who had been urged to protect themselves by scrubbing their nails.

In another large smelter the very dangerous open-hearth method was used and lead poisoning was so frequent and so bad that the company resolved to spare no expense to get rid of it. Following the advice of their physician they put up an excellent bath house and provided soap and towels, but they did nothing about the fumes at the hearths. When I made a second visit more than a year after, I found them much discouraged because lead poisoning was about as bad as ever. Of course I do not mean that personal cleanliness is not important. It is, but not nearly as important as cleanliness of the work place. The rule should be to give the men plenty of opportunity to get clean at the end of the day's work, but to devote most of the available time and money to the control of dust and fumes in the work rooms.

INDIVIDUAL SUSCEPTIBILITY

Everyone in the lead trades knows that there are men who can hardly stand any exposure to lead, while others can handle it for years with apparent impunity. Hirt tells us that from 20 to 30 per cent. of all lead workers are not susceptible to lead and that of the remaining 70 to 80 per cent., something over one-half become poisoned very quickly, the others more slowly. The only accurate figures I was ever able to obtain on this point in an American lead trade showed a smaller proportion of men immune to lead than that given by Hirt. There were two very dangerous white-lead factories which I visited in 1911 and in which every man was examined by a physician at least once a fortnight. The records showed that 35 per cent. of all the men in one factory and 28 per cent. of all in the other were suffering from the effects of lead. But, omitting the newer employees and taking only those who had been employed as long as one year, we found that the rates were 52 and 40 per cent. Only 10 per cent. in one factory and 12 per cent. in the other had been able to resist the effects of the lead for as much as eight years (8).

A few years ago a study of any lead industry in the United States seemed to reveal a large number of over-susceptible men who developed serious symptoms after a short exposure, but it is important for us to distinguish between those who sicken quickly because of an enormous dose of lead and those who respond over-quickly to ordinary exposure. There used to be many cases of the first class in American industry; there still are more cases than we like to think.

An early article on lead poisoning in the white-lead industry in the United States shows that rapid and severe poisoning used to be quite common. Hobbs (18) of Omaha published an article in 1898 based on his experience with a very dusty plant. He had seen twenty-six cases develop after an exposure of two weeks to six months. Some twelve years later this same industry still had a large proportion of rapidly developing cases. Among 120 white-lead workers with acute plumbism, one-half had sickened in less than two months and 68 per cent. in less than six months. These figures are too large to be explained on the ground of individual susceptibility; they mean excessive exposure. The over-susceptible are probably represented by the 6.6 per cent. who became poisoned in less than two weeks, one of them after three days.

The smelting and refining of lead, especially in certain plants, is a very dangerous trade. In 1912, among 167 men with plumbism, no less than 72 per cent. had succumbed after an exposure of less than six months. Here the over-susceptible were the thirty-seven who were poisoned after less than eight weeks' work. That excessively bad conditions in this industry can bring about even more rapid poisoning

is shown by Hall's (19) report of the American Smelting & Refining Co.'s plant at Aguas-Calientes, Mexico. He states that the flue dust men in this plant sometimes develop acute symptoms after seventy-two hours' work and that usually it takes only eight to ten days to incapacitate them. Painters do not often acquire plumbism quickly, but among 100 with lead poisoning in the Cook County Hospital were twelve who came down with it in less than a year's time.

Over-susceptibility is shown not only by the rapid onset, but by the severity of the symptoms. Pratt (2) describes a very severe case of lead poisoning in a printer which must certainly be regarded as an instance of unusual susceptibility because the exposure to lead in the printing trade is so slight. This was a young man of 22 years who had worked for nine years as a compositor and make-up man. He had never been ill in his life before he was taken with acute lead poisoning and died on the fifth day.

The case reported by C. Williams (20) also is one of over-susceptibility. A man who had been teamster in the yard of a lead works was transferred to indoor work where he was exposed to fumes. After five weeks he was sent to the Philadelphia Hospital with acute plumbism, remained there a month and was then discharged cured. He went back to work, but two months later was re-admitted to the hospital and was under treatment for six months. Again he was discharged, but a month later was re-admitted to the insane ward, where he remained for seven months with toxic confusional insanity due to lead. When Dr. Williams saw him seven months afterward he had partial palsy of the arms, muscular tremors of arms, hands, and lips, hesitating speech, and left lateral homonymous hemianopsia.

This great variation in susceptibility often leads employers to argue that they cannot be held responsible for cases of lead poisoning that occur in their works because, if there were really any danger present, all the men would suffer. If they can produce, as they always can, a few elderly men who have worked in lead for years and never had colic or palsy, they believe they have proved their point, but no one would use an argument of this sort about an infectious disease. We all know that there is the widest difference in natural immunity and natural susceptibility to the different infections. You cannot prove that typhoid infected water is not dangerous by pointing to people who went through an epidemic without getting typhoid fever, nor can you prove the uselessness of vaccination by pointing to a few unvaccinated who do not take smallpox.

RACE SUSCEPTIBILITY

There is a general impression among lead men that negroes are more susceptible to lead poisoning than white men. So far as I know this has never been confirmed. It remains an impression. Edsall (21) in his article in Osler's *System of Medicine* quoted Monell, a smelting expert, as saying that negroes are especially prone to lead convulsions. Edsall found that, of six cases of plumbism among negroes in a Philadelphia hospital, three were encephalopathies. There are only two trades in which I have found negroes employed along with white men so that the effect of lead on the two races could be compared and, though I could not find that lead poisoning was more frequent among negroes, I did find a greater proportion of encephalopathy in those who became poisoned. In the white-lead industry only 15 per cent. of the employees were negroes, but four out of nine cases of lead convulsions or delirium were in negroes. Negroes were employed in a smelter where fumes and dust were unusually bad. Taking only the men employed in the worst kinds of work, it was found that eighty-four white men had four cases of encephalopathy, making about 4.7 per cent., and seventy-five negroes had fifteen cases, or 20 per cent.

SEX SUSCEPTIBILITY

The English authorities, Oliver, Legge and Goadby believe that women are at once more liable to lead poisoning than men and more subject to the severer forms. Thus Oliver (22) says that during the six months of 1898, before the law forbidding the employment of women in work with white lead went into effect, there were 350 women employed in such work in Newcastle-on-Tyne and there had been sixty-six cases of lead poisoning among them with four deaths, while the 648 men had had but nineteen cases with one death. It

is evident, however, that the women were doing the very dangerous work of stripping the white stacks and emptying the stoves. In the following six months these women were displaced by men and the men's cases rose to eighty-two.

Arlidge (23) does not believe that women are more susceptible than men. His observations were made in the North Staffordshire potteries. In the hospital there, in what they call the ambulant department. 463 men were treated, 8 per cent. of whom had lead poisoning, and 337 women, 5.05 per cent. of whom had lead poisoning. Yet women did much of the dipping in the potteries and most of the majolica decorating. The Germans do not believe that women are more susceptible than men. Agnes Bluhm (24), writing in Weyl's *Handbuch der Hygiene*, says that if a larger number of women become poisoned, "it is because women usually make much lower wages than men and are less well-nourished and, since they often have to do housework in addition to their factory work, they are more overworked than men." If women work in lead dust they are more likely to carry it home on their clothes and hair than men are.

Our information on the effect of lead on women in America is fortunately very scanty, for we have never employed women in any of the more dangerous lead processes with the exception of lithotransfer work and the finishing of glazed pottery and tiles. Industrial lead poisoning in women is still a rarity in the United States. Of the 268 cases which W. Gilman Thompson has seen in New York only one was a woman. Edsall saw ninety-eight cases in the Episcopal Hospital in Philadelphia, all men. E. E. Pratt gives the details of 109 serious cases of plumbism, two of which were in women. Among the 578 cases listed in the report of the Illinois Occupational Disease Commission, there were only eighteen women. Chicago has four lead trades that employ women in fairly large numbers, the making of lithotransfer papers, soldering tin cans, casting car seals, and founding type.

It is very difficult, then, to compare the susceptibility of men and women to lead in American industry. Lithotransfer work, dusting finely ground lead colors over specially prepared paper, has always been productive of lead poisoning in a considerable proportion of the girls who do the work. But no men are employed here so the figures from this trade are useless for our purpose. In type founding we have not accurate enough figures, nor have we in connection with the use of solder. It is only in the glazing of pottery and tiles that it is possible to make a comparison, and there the figures seem at first to bear out the English theory. In the New Jersey and Ohio potteries there were, in 1911, fifty-seven cases of lead poisoning among 400 women who were exposed to lead, or one in seven, and only eighty-seven among 1100 men, or one in twelve or thirteen. But other factors must be considered before these figures can be taken to show sex susceptibility. There are two distinct branches in the pottery industry in this country; first, the white-ware potteries in which the men are strongly organized and get high wages, but the women do not belong to the union and get poor wages; and second, the art ware and tile works in which there is no organization and both men and women work for low wages. The women in the white-ware potteries had one case of plumbism to every five or six employed; the men only one to every twenty or twenty-one. But in the unorganized potteries and in the tile works where men and women are in the same economic class, all making low wages, there is no such contrast between the two sexes. In 1911 the men had one case of lead poisoning for every six to seven employed, the women one to every eight or nine. The slightly greater incidence among the men was probably to be explained by longer employment, for the women dropped out of the industry at an earlier age than the men did (9).

These figures are too small to be of much real significance and the same thing is true of the statistics on encephalopathy among women. All authorities say that women are more liable to acute cerebral lead poisoning than men and this proved to be true in American potteries and tile works. Among 1100 men there were 87 cases of plumbism with 3 encephalopathies, among 400 women, 57 cases with 13 encephalopathies. Or to put it in another way, the rate of plumbism among men was about 8 per cent., but of these only one in seventeen had the brain form. The rate among women was 14 per cent., but of these one

in four or five had encephalopathy.

The important feature of lead poisoning in women is not their own greater susceptibility to the poison, but the fact that it acts on the generative organs, or rather upon the products of conception, making women sterile, or incapable of carrying a child to term, or of bearing a healthy child. Now these conclusions are not based on any American statistics, for we are fortunate in having none. Married women have not been employed in the lead trades in this country in numbers large enough for us to know what effect lead has on their childbearing powers. But the statistics from England and France are striking enough to leave no doubt as to this effect.

As for the effect on the offspring of lead poisoning in the father, we find very little that is convincing in the literature. Indeed it is a matter of surprise that most of the text books on industrial diseases should speak as positively as they do on this subject since, except for some scanty figures from France, there is almost nothing definite as to human beings. However, two interesting experimental studies bearing on the subject have been carried on in American universities which show that in the lower animals lead poisoning in the father has a decided effect on the nutrition and viability of the offspring. Cole and Bachhuber (25), working at the Wisconsin Agricultural Station, administered lead acetate to rabbits and fowls. In the case of the rabbits the mortality of the young during the first four days after birth was 47.7 per cent. when the father was leaded, as contrasted with 29.2 per cent. when the father was normal. The average weight at birth was 49.8 gm. for the former, 59 gm. for the latter.

C. V. Weller (26) of the University of Michigan used commercial white lead in capsules for feeding guinea pigs. The experiments with leaded males gave very interesting results.

	Free Female Free Male	Mated with Leaded Male
Number of offspring...	58	65
Average birth weight in grams.....	81.5	66.3
Number stillborn.....	3	3
Died first week.....	2	9

A normal female was mated alternately with a normal and with a leaded male. The resulting offspring weighed 79 gm. when the male was normal; 54, 47 and 40 gm., when the male was leaded. This underweight was found to persist through life. There was also a high rate of mortality during the first few days after birth. Nine out of sixty-five offspring of leaded males died during the first week, but only two out of 105 offspring of control males.

As for lead poisoning in children, this is not usually an industrial problem. Fortunately it is very rare to find even fourteen-year-old boys or girls in a lead trade in this country. There are three curious instances of widespread community poisoning from lead industry, including children and non-employed women. One is the poisoning that occurred around the mine and smelter at Broken Hill, Australia (27), where fumes were spread over the countryside, causing plumbism in many of the inhabitants. Another is the family poisoning in certain Hungarian villages where pottery glazing is a home industry (28). The third is to be found in Mexico, but as the company operating the smelter is American and the physician reporting the conditions is also American, we may perhaps count this as an American plant. The instance in question is the wholesale poisoning of the men, women and children in Aguas-Calientes, Mexico, by the fumes from the smelter of the American Smelting & Refining Co. The report describing this last is one of the most extraordinary I have ever read, but as it is tucked away in the pages of a local journal, the *Texas State Journal of Medicine*, it seems to have escaped general attention, as it escaped mine until recently. The author, Dr. H. C. Hall (19), is apparently quite unconscious of the shocking nature of the conditions he is describing and therefore tells us with the utmost frankness of the effects of lead, not only on boys from 10 years up who apparently are employed in the smelter and who get palsy of the legs, but also on the women and babies living in the company houses close enough to the smelter to be poisoned by the fumes. He finds that lactation is affected in these women. Some 22 per cent. of the mothers were unable to nurse their babies satisfactorily. Forty per cent. of these were primiparæ, but 30 per cent. were multiparæ, who had been

able to nurse the babies born before they came to the smelting village to live. He also found that parturition was rendered difficult by uterine inertia, which is rare usually among Indian women, but was present in 21 per cent. of those confined at the smelter. Dr. Hall had the curiosity to test a number of placentas for lead, reducing them first to ash. He does not give us the number examined, but says that he found lead in every instance. He also examined the blood and scrapings from uterine curettements which were done for dysmenorrhœa and found lead every time. No less than 80 per cent. of the babies born in this village had delayed dentition, the first tooth appearing sometimes as late as the thirtieth month. Children who had come to the village with old mastoid infections suffered relapse, little girls had a non-infectious vaginal discharge, latent malaria and rheumatism became active again.

The description of lead and arsenical poisoning among the men in the smelter is sufficiently shocking, but the wholesale family poisoning which apparently went on unchecked, almost taxes one's credulity. Judging from this article the company contented itself with urging personal cleanliness on the families of the employees.

LEAD PALSY

The theory that is generally accepted now to explain the localization of lead palsy is Edinger's *Aufbrauchtheorie* or exhaustion theory, namely, that fatigue is the main factor in the localization of lead palsies. We no longer say that the poison has a predilection for any group of muscles; the group that becomes palsied is the group that has been overused. Mellon (29) of the University of Michigan has confirmed Edinger's theory experimentally on frogs and there are plenty of instances in the American literature of industrial poisoning that bear out the theory. Hall of Aguas-Calientes describes fifty-five cases of palsy in a lead smelter. Only five of these had the typical lead palsy, wrist drop, and these men were all blast furnace tappers. Twelve men had foot drop, five had palsy of the deltoid muscle only, and thirty had the Duchenne-Erb type involving deltoid, biceps and brachialis anticus, three had palsy of the supra- and infra-spinati. In Pratt's group of thirty-six painters, thirteen had palsy involving wrists, or fingers, or arms, or all of these. One had palsy of thc legs also. In his white-lead cases, however, while five had wrist drop, four had other forms of palsy, and the same was true of two out of seven solderers.*

Among twenty-two cases of palsy in white-lead workers in 1910, only five had palsy of the wrists alone, thirteen had loss of power in legs and wrists both, and four in the legs alone. These men were unskilled laborers making coarse movements, lifting heavy pots, shoveling and trucking. A clear instance of the exhaustion theory was related to me by Dr. A. J. Boucek of Pittsburgh. A man had been employed for ten years filling wooden kegs with white-lead paint and had never shown any symptoms of lead poisoning. Then the company he worked for began to use small iron pails instead of kegs. The patient had always held the barrel shaped kegs with his hands placed flat against the sides just below the bulge, but the iron pails had smoothly slanting sides and he was obliged to grasp them by crooking the ends of his fingers over the projecting bottom edge. He found the work far more tiring than his old work had been, and after a few weeks a double wrist palsy developed that lasted many months. In this connection I might mention the statement made to me by an observant manager of a white- and red-lead works who was trying to convince me that lead poisoning took place through the skin. He said: "I have noticed that men who work in the lead with their hands get wrist drop, those who carry loads on their shoulders get palsy of the shoulders, and the truckers who pass to and fro over the dusty floor barefoot or with worn out shoes get the ankle drop."

The fact that an injury may determine the localization of a lead palsy does not militate against Edinger's theory, rather it confirms it. Walsh (30) in 1908 reported a case of wrist drop in a painter coming on within twenty-four hours after he had sprained his wrist.

There is space for only one or two more American contributions to our knowl-

*In his diagram Pratt gives fifteen cases of palsy in painters, only five of them affecting the wrists, ten affecting other parts of the body. But a careful reading of the histories of his thirty-six painters gives the above result.

edge of the lead trades. One has served to clear up the question of danger from fumes of molten lead in the printing trade. This was a subject of dispute and the statements in the foreign literature were far from conclusive. Linotypists in this country were insistent that lead fumes from the pots of linotype machines were responsible for their ill health and asked for laws to require the removal of the fumes. Dr. Earle B. Phelps (7) of the Hygienic Laboratory of the Public Health Service has settled this doubtful point for always. Believing that the contradictory results obtained by different experimenters might be due to the fact that lead when stirred or skimmed or ladled gives off fumes at a temperature at which lead at rest may not give off enough to be recognizable, he reproduced in the laboratory the conditions present in linotyping, monotyping, stereotyping and electrotyping, and found that while in stereotyping and electrotyping the temperature may be high enough to give rise to fumes when the lead is agitated, in linotyping and monotyping there is neither enough agitation nor a high enough temperature to allow of the escape of lead fumes. The discomfort complained of by linotypists when working at machines with no provision for carrying off fumes is to be explained by the fumes from the gas used to keep the lead hot.

There are many interesting individual cases of lead poisoning reported in our literature, but I have space for only one: It was reported by E. W. Larzell (32) of Colorado. A man who was foreman in a sheet lead works had an attack of lead poisoning so severe that he almost died and had to give up his position and go into lead-free work. Sixteen years later he had pneumonia and as resolution was slow and incomplete his physician put him on iodide treatment. The result was a typical ankle drop, the solvent action of the iodide having liberated the lead which all those years had remained stored in his tissues.

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THE PROBLEM OF FATIGUE*

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INTRODUCTION

EVEN an approximately complete discussion of the problem of fatigue would require many hundred printed pages. In the first and theoretical part of the following paper we, therefore, propose to limit our discussion to certain important chemical and physiological aspects of the problem of fatigue in the human organism. We shall make no attempt to review all the experimental work upon this phase of the subject, but shall confine our attention chiefly to certain important contributions that have appeared for the most part since 1903 (Note 1). We shall then proceed (Part II) to review the results of the practical application of scientific and experimental methods to the problem of fatigue in industry. Finally (Part III), we include a bibliography which is necessarily incomplete but which will serve as a working basis for further study.

PART I: THEORETICAL

1. *Fatigue in terms of chemical equilibrium.*

If some mechanical genius should announce to the scientific world that he had devised a gas engine which, while standing still, could replace the wear and tear on cylinders and bearings and pistons, we should hail the discovery as revolutionary. Man-made machines are not of this type but nature's machines, which we call organisms, have precisely this extraordinary power of recuperation. The entire process of power consumption and energy interchange in organisms we term metabolism, and metabolism has both its constructive (anabolic) and its destructive (katabolic) phases. The two processes of metabolism are interrelated in such a way that they constantly tend to balance each other. Physiologists, therefore, speak of a "metabolic equilibrium." The conception of organisms as complex, physico-chemical systems constantly striving toward equilibrium is fundamental for the understanding of any physiological process. For convenience we may borrow from the chemists a scheme to represent the two phases of metabolism in equilibrium.

Energy at High Potential ⇄ Katabolism / Anabolism ⇄ Energy at Low Potential

The two arrows indicate that neither anabolism nor katabolism is ever present alone but that, once the degradation of energy has begun, a reaction in the opposite direction—a tendency to deposit energy at high potential—is developed. Furthermore, both the degradation and accumulation of energy are limited. Now, whereas broadly speaking the truth of our schematic presentation holds for all so-called "vital processes," we are for the moment particularly interested in the problem of the energy exchanges and activities of muscles and nerves.

It is common knowledge that muscular work can not be continued indefinitely; after a longer or shorter time we must

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rest, but, after a longer or shorter period of rest, we find that our energy has returned to its former high level or potential. With these facts fitted into our equilibrium scheme, the relation between work and rest may be written:

Energy at	Work	Energy at
	$\rightleftarrows$	
High Potential	Rest	Low Potential

In chemical terms, the *work reaction* reduces some of the total available energy to low potential; the *rest reaction* restores energy to high potential. The rest reaction is thus seen to be an active, synthetic process.

The chemists are familiar with an enormous number of simple reactions which show this type of reversible equilibrium. A standard illustration will help to throw further light upon the $\frac{\text{work}}{\text{rest}}$ equilibrium. If water is added to ethyl acetate, alcohol and acetic acid result (Note 2). The reaction is written:

$$\underset{\text{ethyl acetate}}{C_2H_5COO\ CH_3} + H_2O \rightleftarrows \underset{\text{ethyl alcohol}}{C_2H_5OH} + \underset{\text{Acetic acid.}}{CH_3COOH}$$

Alcohol and acetic acid are at first formed very rapidly but gradually there develops a greater and greater tendency for alcohol and acid to re-form water and acetate (Fig. 1). A reaction running from right to left is set up and runs concurrently with the reaction from left to right. Finally the reactions proceed with equal rapidity in both directions and are said to be in *dynamic equilibrium*. Considering for a moment only the acetic acid, we may say that after a small amount of acid has been formed, further accumulation of acid slows down the reaction more and more until we finally reach a point where the reaction is limited by one of its own products (Fig. 1).

Turning now to the simple case of an excised frog's muscle, we find that one important reason why we cannot make this muscle raise a given weight indefinitely, why the work reaction cannot continue until all the energy at high potential is consumed, is because of the gradual accumulation of an acid (in this case, lactic acid) (Note 3). The work reaction is thus gradually limited and regulated by one of its own products. If, instead of allowing the lactic acid to accumulate, we remove it either mechanically by washing it away, or chemically by oxidation or neutralization, we find that the work reaction continues much longer.

During and following human muscular activity, the mechanical removal of lactic acid and certain other products of muscular work is accomplished in part by the irrigation of the circulation. The blood likewise deposits sugar in the muscles, thus constantly replenishing the source of high potential energy. Now it is possible for a muscle to work at such a rate that the removal of acid is exactly as rapid as the deposit of sugar. The muscle is then in the condition of dynamic equilibrium. Such a muscle may continue to work almost indefinitely as in the case of the beating heart (Fig. 3).

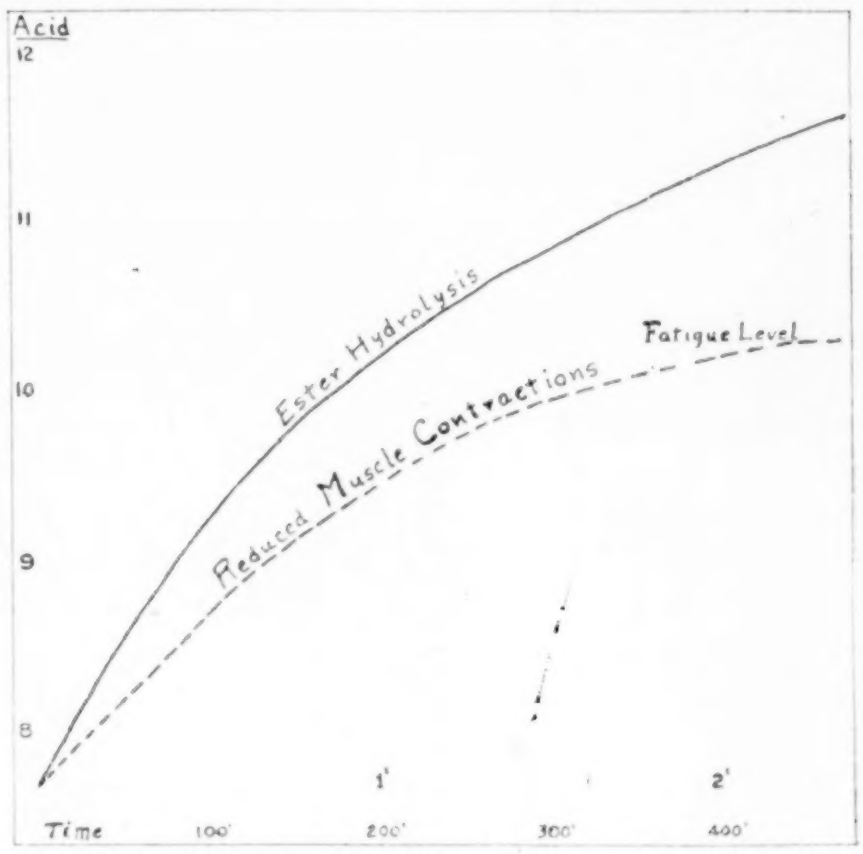

FIG. 1.—Curves showing a self-limited reaction in a simple and a complex organic system. The upper curve shows the course of ethyl ester hydrolysis during a period of more than six hours. (The data are plotted from Knoblauch, O. 1897, *Ueber die Geschwindigkeit der Esterbildung und Esterzersetzung*, Ztschr. f. physik. Chemie, **27**, 268). The lower curve shows the approach to the fatigue level in a contracting muscle. This curve is an enlargement of one end of an ergograph record by Hough (See Fig. 3) *inverted* and smoothed out. In both the simple and complex reactions, the accumulation of acid is the limiting factor. As the curves become increasingly asymptotic, they approach a condition of dynamic equilibrium.

2. *Muscular Work and Fatigue*

This discussion of dynamic equilibrium has brought us to the very center of our problem of fatigue. Fatigue may normally (Note 4) be considered a condition of lowered capacity for work, resulting di-

rectly from the accumulation of the products of activity and varying with the duration, rate and intensity of the performance and the initial strength or capacity of the physical system involved (Note 5). We have purposely omitted here any reference to the supposed phenomenon of mental fatigue. The status of the problem involved in this conception will be discussed in a later section (p. 30). The existence of central or mental fatigue is inferred, but the experimental evidence is by no means satisfactory and cannot well be treated on the same basis as that for physical fatigue.

The experimental investigations of fatigue (we shall understand the term in this discussion to mean *normal* fatigue) are mainly of two sorts: one, experiments upon excised muscles or nerve-muscle preparations of frogs and small mammals; and two, experiments upon human subjects in which single muscles or a limited group of muscles are exercised until their working capacity is much reduced or has disappeared completely. In both types of experiments the muscle is required to raise a weight, and the electrically or voluntarily induced contractions are recorded by means of a lever upon a revolving smoked drum. In both excised and intact muscles fatigue has been estimated in three ways:

I. A muscle is forced, by natural or artificial stimulation, to work against a heavy and rapidly exhausting load, and either the time required for the complete loss of contractility or the time required for the *recovery* of the original irritability is taken as an index of fatigue.

II. A muscle is forced to work against a moderate load, and the time required either for exhaustion or for a return to normal contractility is taken as the fatigue index. This method differs from I only as regards the selection of the weight.

III. A muscle is forced to work against a load so chosen that the height of the individual contractions of the muscle is reduced but reaches a constant level beyond which further reduction does not occur. In this case either the height of the fatigue level or the time required to reach that level is chosen as the fatigue index. A moment's consideration will make it clear that in a given muscle, *provided the rate of contraction remains constant* (Note 5), the only quantity that varies as we progress from I to III is the size of the weight. The interrelations of the three methods for estimating fatigue may best be shown by a simple diagram combined from a study of a great number of fatigue curves. The figure is particularly significant for the cases where the circulatory system is left intact. If we plot the time as abscissae and the height of the contractions as ordinates (Note 5) and keep the working rate constant, we find that with a *heavy* weight we get curves like 1 and 2 (I). (Mosso, 1890, I; Ioteyko, 1903, I).*

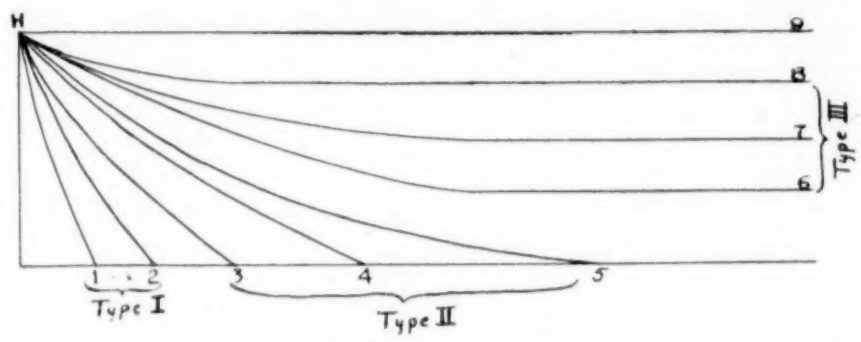

FIG 2.—A diagrammatic representation of the types of curves observed in various investigations of muscular fatigue. All fatigue investigations show curves belonging either to Type I, II or III. A detailed explanation of the practical and theoretical significance of curves of Type III is given in the text.

With a lighter weight, we get curves of the 3, 4 and 5 (II) type (Fletcher, 1902, 2, II; Lee, 1902-1907, 1906, I and Fig. 4), and with still lighter weights a fatigue level appears, like that shown in 6, 7 and 8 (III), (Hough, 1901, II and Fig 3 of this paper). As we pass through the series from 1 to 9 the fatigue curves gradually become more and more asymptotic. Finally, with extremely small weights, the height of the contractions remains constant. In this case there is no indication of fatigue (Note 6).

In our consideration of the various forms of fatigue curves we have assumed the working rate to be constant and the weight alone to vary. Experimentation has shown that a similar group of curves may be obtained by keeping the weight constant and changing the rate of work. In other words: "The height of the fatigue level varies inversely with the rapidity of the rhythm of contraction" (Hough, 1901,

*Text references indicate the author, the year of publication, and the number of the division in the bibliography in which the article is listed.

H.). Fig. 3 illustrates precisely this point very strikingly. After the muscle had contracted for six minutes at a rate (Note 6) of $\frac{C}{R} = \frac{\frac{1}{2} \text{ sec.}}{\frac{3}{2} \text{ sec.}}$ the rhythm was changed to $\frac{C}{R} = \frac{\frac{1}{2} \text{ sec.}}{19\frac{1}{2} \text{ sec.}}$ The muscle promptly rose to its original level and remained there as long as the slower rhythm was maintained. This rise in the height of the contractions with a slowing down of the rhythm corresponds to a shift from curve 6 to curve 9 (Fig. 2), to the level of *no fatigue*. Here, then, is a case of continuous work without an accumulation of fatigue. Obviously, the working rate is very slow.

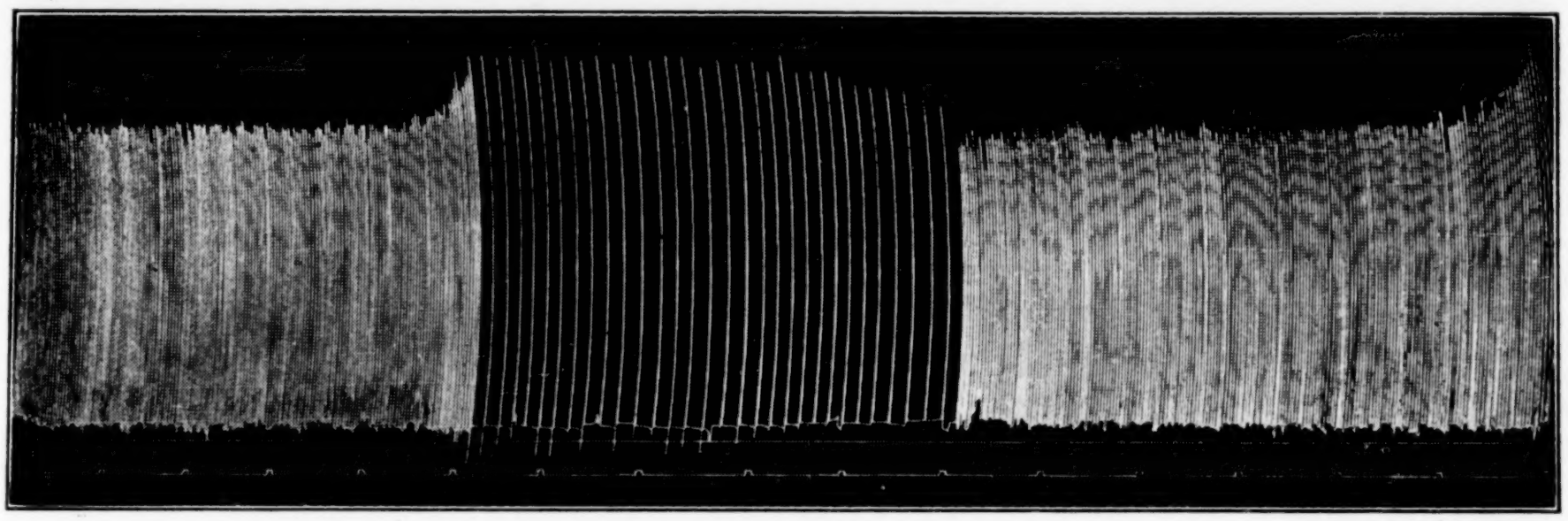

FIG. 3.—A fatigue curve of Type III (Fig. 7, Hough, 1901, II, p. 253) showing the importance of the rate of activity. The fatigue level is abolished after six minutes by changing the rate from $\frac{C}{R} = \frac{\frac{1}{2} \text{ sec.}}{\frac{3}{2} \text{ sec.}}$ to $\frac{C}{R} = \frac{\frac{1}{2} \text{ sec.}}{19\frac{1}{2} \text{ sec.}}$. The fall in the height of the contractions during the first two minutes of the rapid rate indicates the accumulation of lactic acid and other metabolites. It is this fall (from Hough's Fig. 6, loc. cit.) that we have inverted and plotted in Fig. 1. At the fatigue level the muscle is in dynamic equilibrium.

If we turn now to a consideration of the practical question of muscular efficiency, we may say at once that fatigue curves of types I and II do not occur under normal human working conditions. In the course of our daily activities we never exhaust our energies to the point attained in the case of the ergographic records, where one more movement becomes literally impossible. This means that, so far as practical considerations go, we have to deal only with curves of type III. What we are really interested in, practically, is not how long a muscle will require for complete exhaustion or for recovery from complete exhaustion, but how it may operate so as to produce the greatest amount of work, in a given period of time with the least fatigue. And, strange as it may seem, this precise question has never, so far as we know, been experimentally answered by the physiologists (Note 7). Maggiora (1890, II) appears to have been the first investigator clearly to recognize the practical possibilities of intercalating sufficient rest periods between muscular contractions. Using a weight of 6 kg. on Mosso's finger dynamometer, he raised it at a rate of once every 1, 2, 4, and 10 seconds. The mechanical work accomplished by the finger muscles in the course of an hour was found to be thirty-two times as great at the ten second rate as when the contractions were made every four seconds. Maggiora makes the following interesting comment (p. 199): "On a ainsi, pour les muscles de la main, la repetition de ce qu'on observe pour le muscle cardiaque, avec cette difference que, pour le premier, le rhythme doit etre de 10″ pour qu'ils se reposent completement et qu'ils travaillent pendant un temps indefinis."

With an improved apparatus Hough (1901, II) obtained very constant results (Fig. 3) from the contractions of the mm. flexores digitorum of the second and third phalanges of the middle finger (See also Schenk, 1900, IV, 3). The striking uniformity of his curves suggests that his technique might throw much light upon the theoretical question of a muscle's maximum efficiency (Note 8). (Amar, 1915, IV, 3; Ausscheutz, 1914, IV, 3; Bergstroem. 1903, IV, 3; Broca et Richet, 1898, IV, 3; Camus, 1915, 1 & 2, IV, 3; Grandis, 1903, IV, 3; Hough, 1900, IV, 3; Ryan &

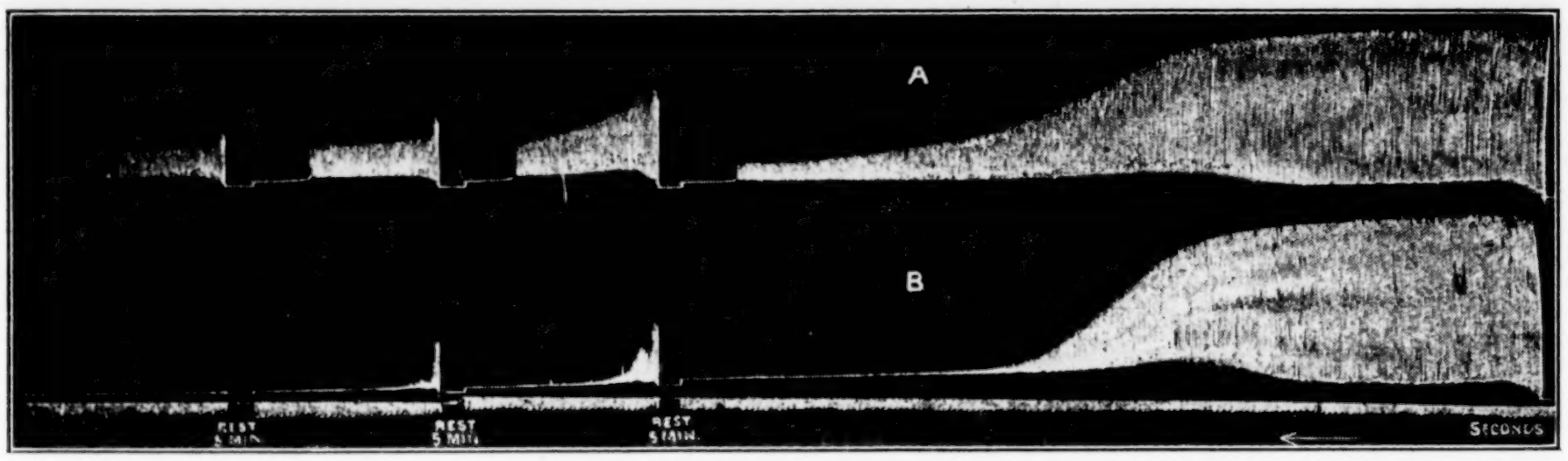

FIG. 4.—Fatigue curves of Type II (Fletcher, 1902, II, Fig. 7, p. 490). This figure shows that oxygen is essential for the recovery of a fatigued muscle, i. e., for the removal of lactic acid after exhaustion. In the upper curve the muscle was kept in an atmosphere of nitrogen and showed only the faintest trace of recovery. The tracings were made by a pair of excised frog's gastrocnemius muscles.

Agnew, 1917, IV, 3; Treves, 1905, I). It is, of course, commonplace knowledge that periods of rest will increase subsequent working capacity. But is it more efficien' to slow down the working rate as a whole i.e., to work for long periods at a slow $\frac{C}{R}$ rhythm, or to work in a series of spurts—a rapid $\frac{C}{R}$ rhythm with frequent periods of complete rest? The efficiency engineers (Taylor, 1911, VIII), claim to have answered this question for the human organism as a whole at least as regards one type of individual, but a definite physiological foundation through carefully controlled laboratory experiments remains to be established (Benedict & Cathcart, 1913, II).

3. *The Varying Energy Level*

In defining fatigue above as the diminished capacity for work we have attempted to draw attention to the fact that this definition is appropriate only for normal fatigue. Scrutinizing the definition further under conditions, which, if not strictly speaking *usual*, are still not uncommon and cannot therefore be called actually abnormal, we find that it is far from adequate. In the first place, it is evident that working capacity may be and frequently is lowered by conditions other than fatigue. And, in the second place, the presence of fatigue is not invariably indicated by a lowering of the capacity for work. This latter criticism brings to mind at once the familiar phenomenon of "second wind." We normally stop an occupation when we meet what William James (1907, 1, I), has vividly called "the first effective layer of fatigue," but if some unusual necessity forces us to continue our activity we find that our sensation of weariness gradually or suddenly passes away and we feel fresher than before. "We have evidently tapped a level of new energy, masked until then by the fatigue-obstacle usually obeyed." (James, loc. cit.). Now these sudden accessions of energy, of which our daily life shows so many examples, have "rendered well nigh futile all the many attempts hitherto made to obtain reliable objective measures of degrees of fatigue of the organism as a whole" (McDougall, 1908-1909, I). "It seems impossible," McDougall continues, "to get the physiologists of the laboratory, the physiologists who are chiefly concerned with the organs rather than the organism, to consider this conception seriously and on its merits. If they occasionally refer to it, it is only to put it aside contemptuously as a naïve survival from the dark ages. Yet those who are in the habit of dealing with the problems of the organism as a whole, the physician and the psychologists, constantly make use of this conception, for they find it impossible to make progress in the understanding of their problems without it. That fact gives the conception a claim to a more serious consideration than it has commonly received from the physiologists." It is not surprising that James's suggestion of "reservoirs of power" and "layer after layer" of potential energy should have been tendered a cold reception among the physiologists. Such purely figurative expressions without factual basis present no object for experimental attack—without which the physiologist is both skeptical and helpless. Since McDougall wrote the words quoted

above, however, Professor Cannon (Cannon, 1915, VI), and his students have thrown a flood of light upon the whole question of energizing influences.

Cannon (loc. cit., p. 217) states that so far as the physical exhibitions of power are concerned, certain highly serviceable bodily changes, some of which are associated with an astonishing increase in muscular efficiency, exemplify concretely and definitely these figurative expressions of the psychologists. The way in which this increase in muscular efficiency is brought about is as follows. Under the stress of emotional excitement and through the action of the sympathetic nervous system, there is poured into the blood from the adrenal glands a secretion of adrenin, a substance having a number of remarkable properties. For example, injected adrenin causes a liberation of sugar from the liver; and sugar, as we pointed out above, is probably the chief source of the high potential energy in muscular activity. Here then is one "energy reservoir," expressed in simple physiological terms. Another way in which adrenin serves to increase muscular efficiency is by increasing the rate and force of the heart beat and therefore the flow of blood through the working muscle. The fatigue products (lactic acid and other substances), are thus promptly swept away and prevented from impairing muscular efficiency. An even more remarkable action of adrenin is its power of restoring the irritability of muscle after the ability to respond to stimulation has been very much diminished by prolonged activity. Cannon (loc. cit., p. 133) says: "What rest will do only after an hour or more, adrenin will do in five minutes or less." (Gruber, 1914, II; Cannon & Nice, 1913, IV, 6; Lagrange, 1912, I). In this case the adrenin seems to act both on the motor nerve plate and on the muscle substance itself.

"It would doubtless be incorrect to attempt to account for all the increased strength and tireless endurance, which may be experienced in periods of great excitement, on the basis of abundant supplies provided then for muscular contraction, and a special secretion for avoiding or abolishing the depressive influences of fatigue" (Cannon, loc. cit., 217). There occurs simultaneously an immensely augmented activity of the nervous system which is of great significance. Anyone who has ever had occasion to work at high tension under great emotional stress for a considerable period knows that the increased efficiency is a temporary matter. Adrenin production cannot be substituted for sleep and normal rest indefinitely. If we draw too deeply and continuously upon our reservoirs of energy we may develop a condition of hyperaesthesia and ultimately suffer a complete nervous breakdown. Thus the same physiological mechanism which will carry the human organism through critical situations by releasing normally inaccessible sources of energy, may ultimately cause practically a complete loss of working capacity. And, as everyone knows, the recovery from a nervous breakdown is a long and tedious process. A reason that is frequently advanced to account for the slow recovery from a condition of hyperaesthesia is based in part upon the experimentally established fact that after extreme muscular activity certain histological changes may be observed in the brain cells (Purkinje cells), and the recovery of these cells is believed (for no very clear reason) to be an exceedingly slow process (Hodge, 1889, III; Vas, 1892, IV, 6; Mann, 1894, IV, 6; Eve, 1896, IV, 6; Pugnat, 1901, III: Dolley, 1916-1917,1917, IV, 6, and others). The experiments of Cannon and his students suggests a different explanation. In the condition of nervous breakdown one outstanding symptom is an abnormal facilitation of conduction in the nervous system. Cannon's work suggests to us that this condition may be due to some chemical change brought about by the action of adrenin either centrally or at the synopses. Such a change would constantly tend to be maintained by the addition of further adrenin to the circulating blood. Recovery would consequently be a long and slow process. From this point of view, nervous breakdown would really be a condition of adrenin poisoning. This conception is probably open to experimental verification (Note 9).

The psycho-physiological effect of certain dynamogenic words such as *Truth, Science, Liberty, the Flag,* etc., are familiar enough. Nearly everyone has experienced an accelerated heart beat and often a feeling of suddenly increased power

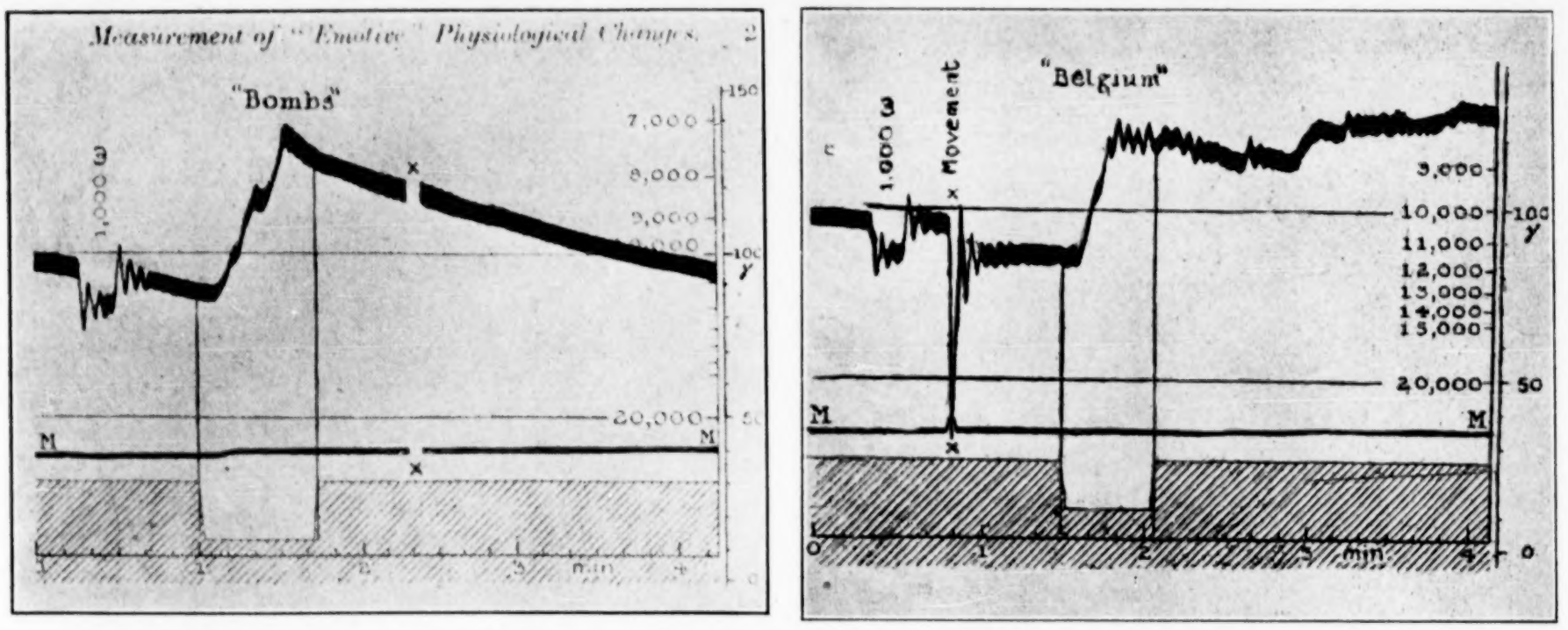

FIG. 5.—Galvanometric measurements made by Professor Waller (1918, VI), showing the psycho-galvanic effect of the energizing words, *Belgium* and *Bombs* upon two individuals who had experienced the Belgian invasion and air raids on Paris respectively. The phenomenon is clearly shown by the rise in the shadow tracing of the galvanometer string. In both cases new levels of energy have been tapped.

at the sound of some suggestive word. Our Figure 5 shows the effect of two energizing words upon the psycho-galvanic reflex of individuals who had had harrowing experiences in the war. In these cases of psycho-galvanic changes the effects of the words *Bombs* and *Belgium* could be directly recorded by Professor Waller with the string galvanometer (Waller, 1918, VI). Such examples are additional objective verifications of the fact of sudden accessions of energy. Combined with our recently acquired knowledge of the physiology of the sympathetic nervous system they constitute an objective basis for further experimental study.

If, then, we are actually in a position to release layer after layer of energy under emotional stress, our problem of fatigue becomes tremendously more complex. Indeed, to say that fatigue is a diminution of working capacity (Florence, 1918, VIII), a definition that constantly appears in the literature, may cover all those cases, such as many of the laboratory experiments, in which no emotion factor complicates the result. But, with the wide range of emotions that occur in different individuals under varying conditions of daily life, especially under the conditions of industrial life, fatigue comes to mean something quite different from a simple diminution of working capacity. We may qualify our original definition, then, by saying that under normal conditions, in the absence of emotive stimuli, fatigue is expressed by a lowering in the capacity for work of the normal individual. On the other hand, in the emotional individual or, under the stress of emotive stimuli, in the normal individual, the presence of fatigue is frequently obscured or masked by a quality and quantity of work that would ordinarily indicate the opposite of fatigue. We recognize fully that in speaking thus we are using the word normal in a loose fashion. As a matter of fact, it is impossible to state at present whether the absence or the presence of emotive stimuli or the unemotional or the emotional individual represents the normal situation. But we feel assured that in the search for a definition of and a touchstone for the condition of fatigue, the emotive situation is too common and too significant to be left out of account.

4. *Central Fatigue*

In our discussion of the nature of muscular fatigue we stated that in muscular activity we have a condition of dynamic equilibrium; when the muscle ceases to respond to a stimulus it is because of the accumulation of the products of metabolism, chiefly lactic acid. Now the work of Abelous (1893, I), Santesson (1895, II), Ioteyko (1903, I), Waller (1885, I), and others has shown that when a muscle will no longer respond to a stimulus through its nerve fibre, it may readily be contracted by stimulating the muscle directly. There appears, therefore, to be

little doubt that the conduction over the motor end-plate within the muscle substance may in some way be blocked by the metabolites. According to these authors, fatigue first interferes with function at some peripheral point. Mosso (1900, I), however, contended that natural fatigue, that is, fatigue brought about by voluntary effort and not by artificial stimulation, is a distinctly central phenomenon. He and Lombard (1890, IV, 3) and Waller (loc. cit.) all claimed that intact human muscles which were completely fatigued for voluntary stimuli could still be contracted by electrical stimulation. Whereas this fact alone does not dispense with the possibility of motor end-plate fatigue, Mosso held (for no very clear reason) that the cause of the loss of voluntary nerve stimulation lay in a depletion of the vital or nervous energy of the entire organism. Subsequent work by Kraepelin (1892, VII), Hough (1901, II), Woodworth (1901, III), Mueller, R. (1901, IV, 3), Storey (1903, 3, IV, 3), and Ioteyko (1903, I), showed that the muscles that had been voluntarily contracted and those that were artificially stimulated were not the same muscles. These experiments serve to invalidate entirely the conclusions as to the fatigue of the central nervous system postulated by Mosso, Lombard and Waller.

The most convincing evidence regarding the locus of fatigue is furnished by the brilliant experimental work of Professor Sherrington (1906, II). A lucid account of this work has recently been given by Ash (1914, VI) as follows:

"Professor Sherrington of the University of Liverpool whose researches into the action of the nervous system have extended the knowledge of that branch of physiology farther perhaps than those of any other investigator, does not believe that central fatigue is due to conditions or changes within the bodies of the neurons. His theory is that the connection between the different neurons is not one of continuity but of contact. This point of contact he terms the synapse, and ascribes to it the first incidence of fatigue. One of his experiments by which he demonstrates this is as follows: A certain nerve center within the spinal cord is selected which forms a union between a number of afferent nerve tracts and a single efferent tract to a given muscle. One of these afferent tracts is stimulated and the stimulus passes through the common nerve center and over the common efferent tract and is thus neutralized in the contraction of the muscle. After a short time this muscular contraction weakens and finally ceases altogether. The stimulus is then applied to another of the afferent tracts and the motor response of the muscle is as strong as at first. Now since nerve fiber is known to be practically unfatigueable, and since the same nerve center, motor end-plate and muscle are involved in both series of stimulations, it is evident that the fatigue resulting from stimulating the first afferent nerve cannot be ascribed to any of these; hence Sherrington concludes that it must be ascribed to the synapse where the afferent nerve tract comes into contact with the nerve center. Professor Sherrington has also shown that if a particular spot on the skin of a 'spinal animal' be stimulated either mechanically (i. e., by pricking or scratching), or electrically, it will elicit certain reflex movements, notably the 'scratch reflex'; but just as in the former experiment, in which the afferent nerve tract was stimulated directly, this reflex movement will presently cease. But if a second point of stimulation be selected a short distance removed from the first, the movement will be immediately resumed. The fatigue from the first stimulations might in this case be ascribed to the sensory nerve endings within the skin. Sherrington, however, does not accept this view, but, on the basis of his results in the previously cited experiment and of others which need not be detailed here, he concludes that it is to the synapse, where the sensory neuron comes into functional contact with the motor neuron, that this initial fatigue must be ascribed."

The working and resting conditions of nerves and nerve cells are quite different from the corresponding conditions in muscle. We know that in the process of nervous conduction no measurable heat is evolved, which suggests that there is practically no energy exchange; nervous conduction can also continue indefinitely without apparent fatigue. Tashiro (1913, 1 & 2, II) detected a production of carbon dioxide during the conduction of the nervous impulse, which he attributed to a metabolic change in the nerve fiber resulting from conduction, but his results have not

been generally accepted. The criticism brought is that the carbon dioxide produced may either have been dissolved in the tissue or have been produced by the connective tissue cells which are always associated with nerve fibers in a nerve. (Bayliss, 1915, I, p. 379.) The metabolism of nerve cells, then, stands in sharp contrast to the chemical changes and heat production exhibited by working muscle. Nervous activity appears to proceed in an astonishingly economical fashion. The most painstaking attempts to demonstrate an energy exchange comparable to the quantity of mental work accomplished have failed. (Benedict & Carpenter, 1909, VI).*

The extremely difficult and intangible problem of mental work lies beyond the scope of this paper. We are quite content to agree with those psychologists who define mental work as "that part of the animal's work which physiology does not account for." (Thorndike, 1914, III, p. 4.) In the present state of our knowledge, central fatigue may be experimentally demonstrated at the synapses of the afferent or intermediate neurones, but the part, if any, that the neurone bodies play in central fatigue is not known. Such expressions as "brain fag" or "mentally tired" which we apply to the sensations of fatigue are popularly associated with the conception of wear and tear of the brain tissue. As a matter of fact, all attempts on the part of psycho-physiologists to demonstrate mental fatigue or obtain a quantitative measure of central fatigue are open to suspicion.

PART II: PRACTICAL

1. *The Tests for Fatigue.*

Ever since the significance of fatigue in connection with school work and industrial processes first began to be recognized, repeated attempts have been made to discover some method for detecting the signs of impending fatigue or of its actual presence. In spite of the conviction that in fatigue we are not pursuing a will-o'-the-wisp but an actual and presumably measurable physical or physiological condition, we must admit that a clean-cut test for general fatigue in man has not yet been discovered. The sensations of fatigue are so universal and easily recognized that the earlier workers were apparently misled into believing that a universal touchstone for fatigue could easily be discovered. In this they were mistaken. The work of the past forty years has gradually convinced physiologists and psychologists of the baffling complexity of the problem; and today we are inclined to be skeptical as to the possibility of finding an unequivocal solution. Are not the variables so numerous that we can never hope for more than some general indications of fatigue, an *effort syndrome*, or combination of symptoms that will point to a vague and general lowering of physiological potential? When we consider that working capacity varies from one individual to the next not only with actual physical or mental equipment, but with such fluctuating factors as general health and habits, interest, training and temperament; and when we recall that the continued exercise of simple functions diminishes the efficiency in other functions in varying degrees, we have mentioned but a few of the complicating factors. Into this mass of complexly interrelated and immeasurable variables the statisticians and psycho-physiologists have plunged, hoping to emerge with a universally valid test for general fatigue. While their efforts have, not surprisingly, been only partially successful they have nevertheless achieved a significant pointing out of the various complicating factors involved in situations in which fatigue presumably plays a part and they have indicated methods by which the problem may be further attacked.

I. Statistical Methods

The practical statistical treatment of the fatigue problem in pedagogy and industry has dealt primarily with output per unit of time. Industrial accidents have also attracted much attention, being suspected of an intimate relation with industrial fatigue. Also general health, consumption of power and proportion of spoiled work have all been suggested as possible measures of industrial fatigue. The most recent analysis of factory statistics in rela-

*Professor Ralph Lillie has recently offered an explanation of nerve conduction based on an analogy with the passage of a wave of electro-chemical activity over the surface of "passive" iron wire. A discussion of this analogy, which seems to us the most significant and helpful in understanding the phenomena of nerve conduction that has so far been suggested, will be found in Science, N. S., 1918, 48, 51.

tion to industrial fatigue is that of Florence (1918, 1, VIII). This author reviews and expands much of his previous work carried on as a member of the British Health of Munition Workers' Committee. Florence is well aware of the multiplicity of variable factors involved in his study and he strikes a warning note at the outset (loc. cit., p. 25) : "It is imperative. . . . for the investigator to set clearly before himself all the factors in industry that may predispose the human organism to fatigue . . . (so) that he may secure evidence as to the comparative importance in fatigue-production of all these different industrial conditions." He then gives a a schedule of these conditions, partly the result of his own practical experience and partly a re-combination of individual and departmental schedules (Weber, 1908, VIII; Roth, 1907, VIII; and Florence, 1917. Interim Report of British Health of Munitions Workers' Committee) previously published. Since "this table has been found of great practical use in the field . . (and) . . may serve as a questionnaire or blank form to be filled in by social investigators," we reprint it in full.

SCHEDULE OF INDUSTRIAL CONDITIONS

I. Length and Intensity of Activity.
II. Factory Conditions: Hygiene and Employment Management.
  A. *Physical: Time and Place of Work.*
    1. Air: Temperature and Humidity; Ventilation and Roomspace; Dust and Fumes, Exhaust Systems; Smell.
    2. Light: Volume, Concentration, Glare.
    3. Noise: Volume, Irregularity, Vibration.
    4. Accident Hazards: Safety Devices; First Aid.
    5. Feeding: Sale of Food; Equipment; Service.
    6. Sanitation: Drinking Water; Rest Rooms; Baths.
  B. *Social and Economic.*
    1. Flow of Work. Depressions and Rush Orders. Routing.
    2. Creation of Staff. Appointment and Dismissal. Permanency of Tenure. Unemployment. Instruction and Supervision.
    3. Maintenance of Production. Incentives: Natural interest in work. Scale, method and assurance of wage payment. Discipline.
III. Nature of the Work.
IV. Type of Workers.
  A. *Sex. Age. Race.*
  B. *Experience.* Date of Entering Industry and Factory. Former Occupations.
  C. *Habits and Home Conditions.*
    1. The Amount and Use of Earnings. Thrift.
    Food: Diet and Time of Meals.
    Stimulants: Alcohol and Tobacco.
    Sleep and Recreation: House Accommodation and Hygiene.
    Support of Dependents.
    2. Method and Length of Transit from Home to Work.
    3. Duties outside Factory (Housework of Women, etc.).
    4. Sexual and Family Relations.
  D. *Point of View* ("Animus"). Trade-Unionism, Patriotism, Economic Self-interest, Herd-Instinct, etc., General Intelligence.

A. *The Output Rate.* Output rate has frequently been selected as a measure of working capacity either of individuals or groups. It is often difficult, however, under factory conditions to obtain exactly comparable units in which output may be measured, and in the case of self-feeding, automatic lathes or looms, where the worker only watches or attends the machine, output measures only the mechanical efficiency of the machine, irrespective of the working capacity of its attendant. Accordingly, in the collection of data the investigator must guard against variations of this sort. The usual method of representing output data is to plot the time against units of output. Curves of this sort (Lee, 1918, 2, VIII, p. 12 & 17; Kent, 1916, 2, VIII), where individual output is considered, vary remarkably, but by averaging a large number of curves it has been estimated that the average output of workers generally reaches a maximum some time between 10 A.M. and noon, and drops off to a minimum toward the closing hour. It is significant to observe that when the output is being deliberately controlled, that is, when operators are "soldiering" or obeying some previously ar-

ranged agreement, the output curve shows no such regular afternoon drop.

Presuming all the data to be valid, the question now arises as to what light the output curve throws on the occurrence of fatigue. We may say at once that if by fatigue we mean a lowered capacity for work, and the drop in output indicates a lowered capacity for work, it must simultaneously indicate, by definition, the presence of fatigue. How much of this fatigue is due to the work and how much to other conditions, output curves do not tell. Several neglected variables have occurred to us in studying the output curves in the fatigue literature. In the first place, *working capacity* is not a constant factor even when little or no fatiguing work has been done. Experiments of Lombard (1892, IV, 3), Storey (1902, V), and others indicate that there probably is a diurnal fluctuation of individual capacity, just as there is of temperature, due to some sort of little-understood central drift. At present our knowledge of this condition is most fragmentary. The morning rise in efficiency is common to both the experimental and the factory output curves. A similar morning rise was found by Martin, Withington & Putnam (1914, IV, 4) in studying the threshold sensitivity of medical students engaged in a regular and strenuous routine. The afternoon drop was observed by Lombard (loc. cit.), but Storey (loc. cit.) records a *rise* in efficiency about 4 P.M. An ergographic study of the normal variations in working capacity under resting conditions, for example among accident or surgical cases in a hospital ward, where approximately normal metabolism may be expected, might throw valuable light on this phase of the output problem. Is the diurnal variation similar for all individuals, and does the curve parallel the factory output curves?

A second variable affecting the output curve involves the question (see p. 26) of the *energy level* at which the individual works. Whereas normally the onset of fatigue lowers an individual's output, under the stress of an emotive stimulus, both working capacity and output may be increased. If the emotive stimulus is sufficiently prolonged (as, for example, in certain domestic situations involving a sick child, an intemperate or lazy wife or husband) it may gradually bring about a serious pathological condition, ultimately a complete breakdown. In cases of this sort, called *abnormal*, but common enough under the nervous and economic strain of modern industrial routine (Goldmark, 1912, VIII), the detection of the gradually accumulating fatigue by a study of output is out of the question. The extent to which this variation of the capacity base line may influence mass output statistics has never been determined. Indeed, the systematic investigation of the entire question of varying energy levels has scarcely begun.

In the study of working capacity, Florence states that "two methods of procedure are possible. Particular cases must either be carefully selected where all factors are known and measurable and no ambiguity exists or need exist, i.e. where data are naturally unambiguous or else subject to control; or, on the other hand, extensive 'mass' statistics must be collected, yielding a sufficient number of cases to eliminate *in the average* all chance ambiguities that do exist." Just what the averages of such mass statistics are intended to reveal Florence does not say, though he states that they "will point the way where detailed causal analysis is most necessary." There seems to us to be one outstanding difficulty in any attempt to detect fatigue by average values of mass statistics. Fatigue is clearly a condition which does not affect all the individuals working at a given task to the same degree; by averaging results of output we obtain a value which obscures both the poorest records and the best records and since normal fatigue is found to a greater degree among the less efficient workers, we thus get a false impression of the working capacity of precisely the individuals we are most anxious to reach. Florence's suggestion that intensive studies of the capacity of individual workers should be made would probably remedy the situation and might, as he hopes, supply a "composite figure that is representative of the results of normal conditions of bodily and mental health and of normal factory management." (Florence loc. cit., p. 37). We believe with Florence that too much emphasis cannot be laid upon the importance of an intensive study of individuals.

B. *Industrial Accidents.* Turning now to a brief consideration of accident distribution as a measure of fatigue, we may say

at once that because of numerous peculiarities in the accident variations actually observed there has been little unanimity of opinion among the investigators as to whether the accident rate expresses human working capacity at all. Detailed studies of the causes of accidents (Bogardus, 1911, VIII) have shown that a large percentage of accidents are avoidable by the injured. Lee (1918, loc. cit., p. 73) states that: "Most accidents have, in part, a physiological origin. Of the various conceivable physiological causes two, inexperience and fatigue, are especially potent." He illustrates the correlation between inexperience and the number of accidents in the case of a large munition factory during a period of seven months (p. 75) by a most convincing graph. The second correlation, between fatigue (as indicated by diminished output) and accident distribution in the course of a day is far less warranted by the evidence. Lee states (p. 14) that: "Most of the tabulations that have been made agree in showing that as output diminishes in each spell, coincident with the progress of fatigue, accidents increase in number—the curve gradually rises through the spell." Our own study of output curves has led us to quite a different conclusion. The outstanding feature of a large number of investigations is the contradictory nature of the relations that appear to exist, in the morning and afternoon spells, between output and number of accidents. Except in the case of heavy muscular work (Lee, loc. cit., p. 17), Lee's own figure as well as those of Florence (see particularly the instructive series of Accident Distribution curves on pp. 45, 47, 49, 55, 59 and 61 of Florence's *First Report*) show that output does not decrease progressively during the morning spell. There is an initial rise and in many cases output is at a maximum between 10 A.M. and noon (Fig. 6). During this same period accident frequency also rises and also often reaches its maximum. (Kent, 1916, 2, VIII). In the afternoon spell, on the other hand, when output decreases almost steadily, accidents again rise to a maximum, usually between 3 and 4 P.M. Thus output and accidents both *increase* throughout the morning, whereas in the afternoon output decreases while accidents attain a second maximum. In other words, when efficiency is measured in terms of output, accident distribution seems to be correlated in one case (A.M.) with an *increase*, and in the other (P.M.), with a *decrease* in efficiency. Clearly the relation between output and accidents is not so simple as Lee and others have supposed. Variations in shop lighting and in the constancy of the danger of operation are at least two factors which further complicate the situation. In order to place this question upon a firm scientific basis, we must have figures showing the output and accident distributions in the same group of workers during the same interval of time. The only available figures, so far as our experience goes, which approach these conditions, we have plotted from a table given by Florence (1918, 1, VIII, p. 66). In our figure the total output, as measured by power consumption, of a highly organized munition factory supplied the data. Of the figures Florence says (p. 65): "For each hour of work for six months the number of accidents is recorded." Until such data have been most critically collected and plotted, it is impossible to advance an opinion in the matter that shall have scientific validity.

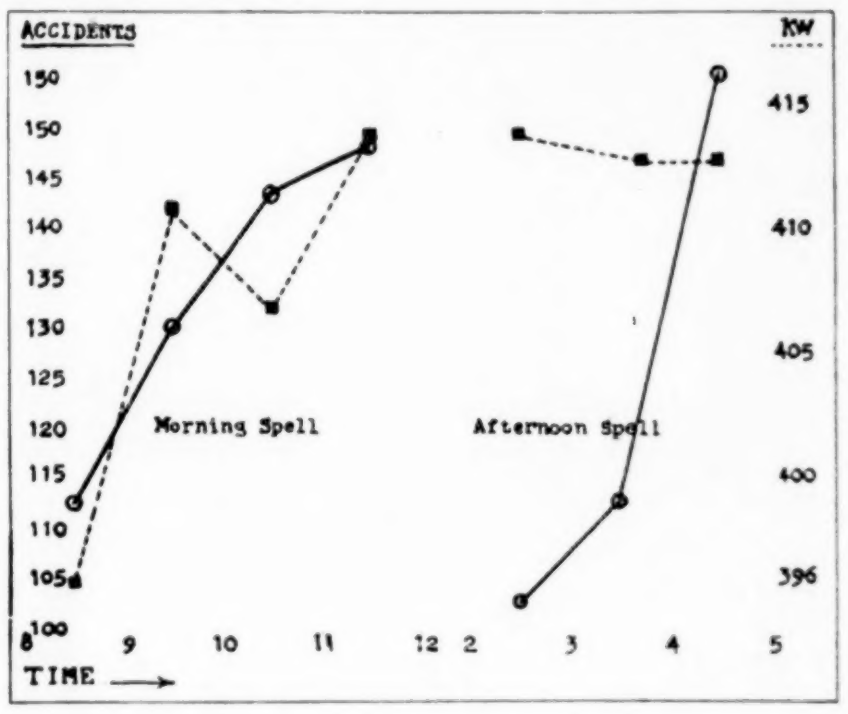

FIG. 6.—The distribution of accidents (solid line) and output as measured by power consumption (dotted line), plotted from data gathered by Dr. Florence. The number of accidents per hour for a period of six months supplied the figures in the left hand ordinate (*Accidents*). The kilowatt consumption per hour for the same period is given in the right hand ordinate. The absence of a consistent correlation between accidents and output is obvious.

C. *Lost Time and Sickness.* A recent study of sickness among industrial workers by Loveday is included in the Interim Report of the British Health of Munitions

Workers Committee (1917, 1, VIII). We agree with Florence when he says (p. 76) that: "Sickness records probably indicate an extreme stage of fatigue among a few and a diminished working capacity among many." The former case would include incipient or advanced psycho-neuroses, the latter what we have termed *normal* fatigue. The sickness records are particularly valuable and significant when a plant is experimenting with a change of hours; an increase in sickness rate whether hours are increased or diminished would be a valid cause for suspecting an increase of fatigue among the workers. It must be kept in mind that the output figures attained under either a reduction or increase in working hours will say nothing of the presence of fatigue unless careful sickness and lost-time records are kept. An increased output with shortened hours, for example, may be the result of anxiety on the part of the workers lest their wages should be reduced, not necessarily a sign of reduced fatigue and increased efficiency. We shall discuss this question somewhat further in connection with our consideration of industrial efficiency.

II. Psycho-Physiological Methods

An excellent critical résumé of the various psycho-physiological tests that have been proposed for diminishing functional capacity, both mental and physical, will be found in Whipple's *Manual of Mental and Physical Tests* (1914, VIII, Vol. 1). Whereas many of these tests have an important theoretical bearing upon the problem of normal fatigue, their practical application in the case of industrial fatigue has been disappointing. In its second report (1916, VIII, p. 17), the Committee on Fatigue of the British Association for the Advancement of Science states that: "On the whole, in spite of their experiments in school and laboratory, the work of the psychologists is still for the most part the reverse of illuminating for the problems of industry." There appear to be two chief reasons for the small success attained in applying psycho-physiological laboratory methods in the factory. 1. It is obviously impossible to reproduce factory processes and conditions in the laboratory or laboratory conditions in the factory; and 2. Psycho-physiological tests have frequently been introduced prematurely under factory conditions without adequate laboratory verification. (*Vide infra*, p. 34.)

In our discussion of neuro-muscular fatigue we have pointed out that the establishment of the existence of a fatigue level—a rate and amount of contraction which a muscle may attain and keep to almost indefinitely—is the most important practical contribution that ergographic studies of muscular activity have made. (Hough, 1901, loc. cit. and Schenk, 1901, loc. cit.) Quite apart from the fact that the raising of a weight by the repeated contractions of a single finger or finger joint does not in all cases adequately isolate a single muscle, ergographic work is very much more localized than any industrial process. Studies of the rate of recovery of completely and rapidly exhausted muscles have but little bearing on the rate of recovery of partially fatigued muscle groups resulting from a day of industrial activity.

The tapping tests in their various forms, the aesthesiometric tests and the computation and cancellation tests and many others of this type (Whipple, 1914, VIII, Vol. 1; Thorndike, 1914, III; Kraepelin, 1898, III; Binet, 1901, IV, 4; and others, see Bib. IV), are even further removed from the operations of industry than are the ergographic tests. As Muensterberg (1913, VIII) has repeatedly emphasized, unless the concrete situations are reproduced *in toto* in the tests, some essential and determining factor may have been overlooked. The various tests which we have just listed obviously represent highly artificial conditions and, as a rule, succeed in measuring only the degree of attention which the subject happens to give to the work in hand; they clearly lack objective validity.

In his two interim reports of *An Investigation of Industrial Fatigue by Physiological Methods*, Professor Kent (1916, 1 & 2, VIII) has experimented with no less than eight tests for fatigue, ranging from Kraepelin's modification of Mosso's ergograph to what Kent calls "a complex dilemma test." The latter consists in measuring the time that elapses between the disclosure of a colored card by a dropping shutter and the striking of a correspondingly colored key. In attempting to determine fatigue with this color test, the

reaction times in the morning and in the evening were measured in hundredths of a second. The reaction time is said to have been longer in the evening than in the morning, but a careful study of the tables (pp. 13, 14, 1st Report, 1916, 1, VIII) and the charts (No. 8, p. 19 and No. 9, p. 21, 2d. Report, 1916, 2, VIII), shows that in some cases the reaction time was longer and in other cases shorter after a day's work. Indeed tests made on the same individual on the same day showed in one case a rise and in another a fall in reaction time—variations which are after all not surprising when we consider that Kent's test requires the complete coöperation of his subjects. It is again mainly the attention factor that is actually in process of measurement, while the amount of variation obtained would alone be enough to make the test extremely doubtful.

In order to reproduce more nearly the working conditions of industry and especially the mental attitude of the worker, McDougall (1908, I, p. 487) has suggested a method for estimating fatigue which "seeks to keep interest at a maximum throughout, the task set being of the nature of a sprint." McDougall's test consists essentially in successfully jabbing with a pen at a series of irregularly distributed spots on a moving cylinder. The rate of the rotating drum is increased or decreased and the subject is given some other task to be carried on concurrently. This method claims, somewhat obscurely, to measure after a half hour's interval "the degree of fatigue produced by an effort sustained for only about three minutes." When we consider that by this test we are measuring loss of coördination capacity, it is evident that, under ideal conditions, the theoretical soundness of McDougall's method admits of no doubt. Inadequate coördination must be recognized as an outstanding cause of many industrial accidents, but coördination power is an exceedingly difficult factor to measure. The attention factor enters all purely subjective tests and an apparent loss of coördinating ability may in reality be a lack of interest or attention on the part of the subject. This complication might be partially met by the introduction of some simple incentive, an interesting monetary reward, for example, for the attainment of a certain score. The development of simple methods for measuring coördination power presents a most promising direction for further work.

The attention factor and other subjective complications have led numerous investigators to the study of more objective methods of fatigue measurement. Attempts have been made to correlate fatigue with a variety of simple and coördinated reflexes such as the knee-kick (Lombard, 1887, IV, 5; Dodge, 1910, IV, 5), the eye-wink (Dodge, 1913, IV, 5), the pulse-rate (Binet & Henri, 1898, III), the blood pressure (Weber, 1914, IV, 3), and a modified vascular skin reaction of Maret (Ryan, 1918, IV, 5). In all these reactions the outstanding difficulty has been to correlate the magnitude of the changes in the reflexes with the degree of fatigue. In the case of the blood pressure Weber (1914, 2, VI, p. 290) has reported an increase with moderate muscular work but a distinct decrease when the working muscles become fatigued. If this reaction should prove to be uniform, it might serve as a useful index of fatigue but Weber's method has the practical difficulty of requiring complicated physiological apparatus. Furthermore, the method has thus far been applied, so far as we know, to trained laboratory subjects only.

Ryan's (1918, loc. cit.) test for fatigue consists in making, by means of an ingeniously devised blunt instrument, a stroke on the palmar surface of the forearm. After a brief interval a white streak appears and the duration of this streak, which is shorter in the fatigued individual, is a measure of the fatigued condition. According to Lee (1918, VIII, p. 15), "The curve of duration of the streak falls during the forenoon, indicating fatigue, rises somewhat during the luncheon hour indicating restoration, and falls again to a minimum during the afternoon. If the subject spends the half-day resting instead of working, the fatigue fall of the curve does not occur and a rise may result." An extensive experimental study of the practical applicability of Ryan's test to industrial conditions is being carried out under the Public Health Service. Our own limited experience with the skin reaction test has demonstrated: first, a wide variation of intensity in different individuals; and second, a lack of sharpness in the end point of the reaction, i.e. the beginning of the

fading of the white streak. The latter difficulty may be a question of experience and we must therefore reserve judgment until the report of the industrial tests appears.

A final group of fatigue tests are those involving the production of chemical changes in the body as a result of activity and the quantitative measurement of the chemical reaction products. Exact studies of lactic acid production in muscle working under laboratory conditions have shown very definite and constant relations to exist between the quantity of acid produced and the amount of work accomplished (Fletcher & Hopkins, 1917, II).

These results are of great theoretical significance but, obviously, do not constitute a practical method of attacking the question of industrial fatigue. More recently, however, Ryffel (1909, II) has shown that lactic acid may appear in the urine after extreme muscular exercise; and Hastings under the direction of Professor Lee has found (Lee, 1918, loc. cit.) that the urine of day-workers in munition factories has a higher order of acidity (hydrogen ion concentration) in the evening than in the morning. Resting subjects used as controls showed just the opposite condition—a slightly greater alkalinity in the evening than in the morning. The nature of the diet must of course be taken into consideration in all measurements of urine acidity. It is well known that a high percentage of meat will increase the urine acidity, while a vegetable diet causes the urine to show a lower order of hydrogen ion concentration. These variables must be carefully controlled before we can hope to obtain quantitative estimates of fatigue by urine acidity measurements, an experimental necessity that Hastings clearly appreciates, for the diet factor in general, and the complications brought about by varying diets, are now being investigated under carefully controlled experimental conditions.

III. Conclusions Regarding Tests for Fatigue

Our study of the various methods that have been suggested as tests for fatigue has brought up a number of questions and led us to the following conclusions:

1. Statistical studies of output, which show production falling off toward closing time give no accurate picture of the degree to which the lowered working capacity, i.e. fatigue, is due to the work that has been done. Diurnal fluctuations in working capacity and long continued emotive stimuli may affect individual output curves so as to render the commonly accepted inverse correlation between output and fatigue invalid. To say that such individual fluctuations will disappear when mass output curves are plotted is true, but serves only to obscure the answer to the question of fatigue in the cases of the fluctuating individuals. Since normal fatigue is associated more with the less efficient workers, and accumulative fatigue is often associated with a high output, *intensive studies of individual outputs and general health are urgently needed.*

2. What is the relation between the distribution of accidents and fatigue? Why do accidents and output both increase in the morning spell and accidents reach a second high point in the afternoon when output is falling off? An extended study of accidents and output in the same group of individuals is suggested as a means of furnishing a statistical background from which valid deductions may be made.

3. Psycho-physiological tests for fatigue which presuppose the sincere coöperation of the test subjects are impracticable under industrial conditions.

4. Coördination tests that are in the nature of a "spurt" (McDougall, 1908, loc. cit.; Miles, unpublished experiments), and present a chance to make a definite "score," reproduce more nearly the psychological conditions of industry. This type of test offers a hopeful field for further work.

5. Of the various reflexes that have been suggested as correlates of fatigue, nearly all show such wide variations that no unanimity of opinion exists as to the quantitative significance of these variations. Weber's test showing a rise of blood pressure with moderate work and a distinct fall after extensive work and the onset of fatigue (as shown by an ergographic record) may prove to be of value in detecting normal fatigue. Exact quantitative relations between rise and fall and the degree of fatigue have not yet been established.

6. Objective tests for fatigue such as Ryan's vascular skin reaction and Hasting's test of urine acidity may, upon further critical development, and control,

prove to be of practical aid in detecting "normal" industrial fatigue. Complete reports of these two tests have not yet appeared.

2. *Industrial Fatigue and Efficiency*

In examining the condition and possible prevention and cure of industrial fatigue, we are primarily interested in the lowering of working capacity, either immediately or ultimately. The angle from which the problem is most usefully attacked is that of efficiency—what we are concerned with is the human working machine—how best to steady, increase and conserve its efficiency. Fatigue in this connection comes to mean really a cumulative effect, a more or less permanent lowering of working capacity due to a condition of overwork or overstrain resulting typically from a too rapid consumption of the industrial worker's available energy. The available working energy has been consumed at a rate exceeding the rate of restoration of energy during the worker's rest hours. The fatigued industrial worker is not, then, simply the individual who is weary at the close of a day's work but one who, having rested insufficiently, comes to his job, day after day, with a diminished working capacity. Workers suffering from "industrial fatigue" are spending their physiological capital; and may ultimately come to bankruptcy in the form of a complete breakdown. The problem of industrial fatigue boils down, then, to the practical question of detecting the signs of incipient psycho-neuroses and guarding against the onset of these conditions.

It is of the utmost importance to bear in mind the fact that the familiar bodily sensations of weariness are in no sense a reliable index of the true state of diminished working capacity. We have seen in our consideration of the theoretical aspects of muscular fatigue that a diminished capacity for work advances progressively and may be well developed before the individual becomes conscious of any sensation of weariness. This is particularly apt to be the case under the pressure of an emotive stimulus, which, if protracted, may lead to a mild or ultimately to an extreme form of nervous breakdown. The past four years have provided abundant examples of long drawn-out intensive activity. Every conscientious person has been working at something with an unusual drive, and throughout the country the industries have been urging increased output by every sort of emotional as well as financial appeal (Note 10). In passing through the factories one saw the national emblem almost invariably in evidence together with signs bearing the familiar "Do your bit", etc., or, specifically, "The Germans are making more propellers than we are! Are *YOU* responsible?" etc. These tactics on the part of the industries have probably resulted in a depletion of the general health of industrial workers—to what extent we cannot gauge at present. Moreover, any attempt to estimate the causes of the present widespread industrial unrest must not fail to take into consideration the inevitable reaction from the prolonged state of high nervous tension since 1914. Actual war conditions obtained in the United States, relatively for so short a period, that the relation between output and increased hours has been less extensively investigated than in Great Britain, where the need for increased and speeded output was more drastic and lasted over a longer time. In Great Britain, also, industrial managers very naturally attempted to increase output by emergency tactics.

In the munitions factories hours were frantically increased, resulting, to the astonishment of the employers, in an alarming decrease in output. The situation was so serious that a committee was appointed by the British Minister of Munitions with the concurrence of the Home Secretary "to consider and advise on questions of industrial fatigue, hours of labor and other matters affecting the personal health and physical efficiency of workers in munition factories and workshops" (Florence, 1918, 1, VIII). Under the chairmanship of Sir George Newman, M.D., and with the coöperation of numerous other medical authorities and government factory inspectors, the committee published twenty memoranda and one Interim Report. (U.S. Bureau of Labor Statistics, Bulletins Nos. 221, 222, 223, 230, VIII.) Before considering in detail the important results and conclusions of the British Munition Workers Committee, we may briefly discuss three classical industrial experiments dealing with the relation of output and efficiency to the length of the working day.

I. The Length of the Working Day

One of the earliest industrial experiments in shortening the day's work was carried on during 1893 at the Salford Iron Works at Manchester, England. The primary object of the experiment was "to prove how far the widespread desire for shorter hours might be met without danger to the mechanical trades." (Mather, 1894, VIII.) Although no figures are given, the report states that when the output for the year 1893 on a forty-eight hour week schedule was compared with the average output of the previous six years (on fifty-four and fifty-three hour schedules), production was found to have increased. Selling prices were slightly lower during the experimental year so that the cost of wages in proportion to turnover rose 0.4 per cent. Oddly enough, however, a reduction in the cost of gas and electric lighting and wear and tear on machinery showed a saving of 0.4 per cent, exactly counterbalancing the debit from the increased cost of wages, so that the management came out even. Mr. Mather draws the following general conclusion, "We seem to have been working in harmony with a natural law instead of against it. . . The most economical production is attained by employing men only so long as they are at their best. When this stage is passed, there is no true economy in their continued work." (Mather, loc. cit., pp. 25-26).

The experience of the Salford Iron Works is particularly instructive since it shows the beneficial effect of the reduced weekly schedule to have been permanent. It is frequently pointed out that a reduction in hours may tempt employees to speed up their work, fearing lest their wages be reduced because of a lowered output. The general health of the workers must therefore be carefully watched for a considerable period after hours have been reduced. As we shall see further on a record of health insurance or of lost time will generally supply the desired information. That the success of the eight hour schedule at the Salford Iron Works was felt to be unequivocal, however, was expressed by Messrs. Mather and Platt in their reply to the inquiry by the United States Bureau of Labor asking whether at the end of eleven years, their works were still on an eight hour basis. The reply, dated May 24, 1904, stated that: "Our experience since the first year in which it (the eight hour system) was tried has fully borne out the conclusions then arrived at, and we are fully satisfied that as regards the comparison between eight and nine hours per day, the balance of advantage is in favor of the shorter period." (Goldmark, 1912, VIII, p. 141.)

The second experiment in reducing the length of the working day was made at the Engis Chemical Works near Liége, Belgium. The work of this company consisted in the reduction of zinc blend and the transformation of the liberated gases into sulphuric acid. The occupation was a distinctly dangerous one, the employees being exposed to poisonous gases and to extreme heat. Under the two-shift system and a working period of ten hours a day, the sick benefit fund showed a constant and alarming deficit. Moreover the workers, who had originally been recruited from a fairly vigorous and healthy stock showed an evident and rapidly increasing physical deterioration. The manager of the works, M. L. G. Fromont (1906, VIII), therefore determined to reorganize his labor force on a three-shift basis, thus reducing the work day to eight hours. The benefits resulting from the change are described most interestingly by Miss Goldmark (1912, loc. cit.). In less than six months after the beginning of the experiment "the workers had *equalled* in seven and one-half hours the previous output of ten hours, and the daily wage for eight hours' work equalled the wage previously earned in ten hours." The hourly output was ultimately so much increased that the eight hour day showed a 33.33 per cent. greater total output than had the ten hour day. That the strain of the increased output was not injuring the worker was shown by the progressive increase of receipts over expenditures in the sick benefit fund. Finally, the total cost of production fell 20 per cent. "Thus in the new organization of work technical perfection was not sacrificed nor neglected. The amount and quality of the output improved progressively, together with the moral and physical improvement of the labor force." (Goldmark, loc., cit., p. 149).

The third and most complete and painstaking study of the effects of shortening

INCREASE IN EFFICIENCY UNDER THE EIGHT HOUR DAY OF 233 PIECE WORKERS AT THE ZEISS OPTICAL WORKS, CLASSIFIED BY AGES.

(Ages were reckoned from April 1, 1900. Length of service reckoned according to years spent in the firm's employ after the eighteenth birthday.)

Ages	No. of Workmen	Average Ages	Average Length Service	Average Piece-Rate Earnings per Hour in Pf.		Ratio of Increase
				9-Hr. Day	8-Hr. Day	
22-25	34	23.5	5.5	55.3	65.2	100:117.9
25-30	69	27.3	7.9	62.2	72.6	100:116.7
30-35	69	32.2	10.1	65.1	74.8	100:114.9
35-40	40	37.7	12.7	60.6	70.2	100:115.8
Over 40	21	45.3	15.3	63.3	74.3	100:117.4
Total	233	31.6*	9.6†	61.9	71.9	100:116.2

*Maximum 53, minimum 22 years.
†Maximum 33, minimum 4 years.

the work day was made by Ernst Abbé at the well-known Zeiss Optical Works at Jena, Germany (Abbé, 1901, VIII). Abbé's work is now so familiar to students of industrial efficiency that in spite of its outstanding excellency and thoroughness, we need give it but brief mention. In 1900 the work day at the Zeiss Works was abruptly changed from nine to eight hours, as a result of a careful consideration of the success of a reduced work day at the Salford Iron Works and the Woolwich Arsenal Works in England. The experiment at the Zeiss Works was planned to run one year. In determining the effects of the shorter day, Abbé compared the earnings of piece workers for the year before and the year after the change in hours was made. To make this comparison strictly objective and to eliminate so far as possible all chance variations, only the output of workers who had been with the firm four years and who were over 22 years of age, was considered. Workers who showed more than 300 hours of lost time or whose health seemed below normal were likewise eliminated from the calculations. This left 233 workers and the increase in efficiency of this group under the eight hour day is best shown by the following table (Goldmark, 1912, VIII, p. 159).

Abbé recognized clearly the importance of discovering just where each individual's maximum lies, though he considered this problem essentially a matter of special investigation. From his own statistics and from other experiences in Germany and England he drew the general conclusion that for about three-fourths of the industrial workers of Germany a nine hour day was unnecessarily long for attaining the maximum output and eight hours was not too short. In the interest of economic development and German national efficiency he, therefore, made a recommendation which is considered radical in some quarters even to-day—the gradual reduction of the work day to eight hours for all German industries.

The English, Belgian and German experiences with a reduced work day have been widely corroborated both in this country (Note 11) and in Europe (Webb & Cox, 1891, VIII; Frankfurter & Goldmark, 1915, VIII). The most recent contribution to the problem is the work of the British Health of Munitions Workers Committee (Bull. U. S. Bureau of Labor Statistics, Nos. 221, 223 and 230,

COMPARISON OF RESULTS

Operation	Speeding up of Operation Possible	Reduction in Weekly Hours of Actual Work	Alteration in Total Output Effected
Men sizing	Throughout, and without limit	58.2 to 51.2 = 7.0	+22
Women turning fuse bodies	Throughout, to a limited extent	66.2 to 45.6 = 20.6	+ 9
Women milling a screw-thread	For a fifth of the total time taken	64.9 to 48.1 = 16.8	− 1
Youths boring top caps	Not at all	72.5 to 54.5 = 18.0	− 3

VIII). The committees' data were gathered under highly abnormal conditions but these very conditions presented a particularly favorable opportunity for studying such questions as overtime, and night work. The relation among British munition workers of the reduction in working time to output was studied in great detail by Dr. Vernon (Mem. 18, 1917, VIII). An improved output always appeared in cases where the speed of the operation was not dependent upon automatic regulation of the process by the machine. In a study of four separate operations involving varying degrees of this automatic element, Vernon found the alteration of output to fluctuate between +22 per cent. and —3 per cent. From the table on page 39 (Vernon, loc. cit., p. 9) "it will be seen that a reduction in the weekly hours of work varying from 7 to 20.6 in the different operations in no case produced more than an insignificant diminution of total output, whilst on an average it produced a distinct increase."

Dr. Kent's study of the unfavorable physiological effects of overtime adds little to our information on the subject for the reason that the individuals were unfortunately selected in favor of the outcome of the experiment. On page 38 (Kent, 1916, 2, VIII) there appears a "table showing output of a worker engaged during eight hours per day compared with that of three similar workers engaged during twelve hours per day; and also the output of workers before and after the abolition of overtime." The workers in this case were women engaged in winding bobbins. The tables show, briefly, that the output of the eight hour worker is greater by more than 8 per cent. than the average total output of the "three similar workers" working twelve hours per day for the first two weeks, and ten hours per day for the second two weeks of the experiment. A comparison of the eight hour worker (No. 14, a) with the "three similar workers" shows, however, that the former was a woman 32 years old who "had worked as a winder at the mill for about seventeen years" (p. 68), whereas the other three workers were girls of 16 and 21 years and, as their records show, relatively inexperienced winders. Overtime studies in general have shown that in the long run the system is uneconomical, both financially and physiologically. The higher wages demanded for overtime work and the loss in efficiency on the part of the workers form an obviously unpractical combination.

In deciding upon the proper length of the work day, both the nature of the operations and the capacity of individual workers must be considered. In cases where the work involves a variable human effort factor the physiological evidence strongly favors an eight hour limit. It should be borne in mind that even where original output is merely maintained or slightly decreased as a result of shortening the work day, the physiological gain to the workers' general health and the strengthening of their morale is of material benefit to the employer. The beneficial psychological effect upon the industrial workers of a voluntary shortening of the work day as compared with the compulsory shortening resulting from a walk-out can scarcely be overemphasized. Industrial workers as a class are frequently suspected of desiring practically an indefinite shortening of the work day. "If they get eight hours, they'll want six" is the alarmist's cry. It is certainly significant that in the only instance where the workers as a class have had a chance to express an opinion on the subject they have decided in favor of a universal eight hour day and against night work and overtime for women and minors (Nation, 1919, VIII). The economic outcome of such an arrangement will doubtless be questioned by some, but anyone who will trouble to read with an open mind the physiological evidence against too long hours, night work and overtime for women must feel that the men who planned such a radical industrial program were possessed of a profound wisdom and social vision.

II. Scientific Management

In an earlier section (p. 26) we have referred to Dr. Taylor's well-known efficiency studies. In his book on Scientific Management, Taylor (1911, VIII) states that his mathematical associate, Barth, discovered the law governing the tiring effect of heavy labor on a first-class man. "And the law is," says Taylor, "that for each given pull or push on the man's arm it is possible for the workman to be under load for only a definite percentage of the day." Just what this statement is intended

to convey is not clear. In the absence of any mathematical proof and all but the most fragmentary published data, we must simply accept Taylor's statement on faith. But we cannot accept the physiological criterion, "the tiring effect of the work on the man," which Taylor used to determine the presence of fatigue. And though we marvel at the increase in Schmidt's capacity for handling pig iron, we also wonder how well he lasted. So far as we can discover, this phase of scientific management has not received the attention that it deserves. True efficiency must be measured in terms of the maximum work that can be accomplished by an individual without the loss of his general health. In recent years scientific management has unfortunately developed along the lines of highly specialized "motion studies" (Gilbreth, 1912, VIII), the object of which has frequently been the attaining of a basis for a proper piece rate or bonus system. The psychological effect of having their motions timed has led many workers to believe that scientific management was merely a special sort of drive. And it is obvious enough that in the hands of an unscrupulous manager it might become exactly that. The labor unions, furthermore, very soon discovered that the principle of the bonus system is the principle of individual bargaining instead of union bargaining. Now, union bargaining has a deeper meaning than the mere formal negotiations involved in the arranging of a wage schedule. It implies the oversight of the individual contract and the power to demand that this contract conform to the wage schedule. In the bonus system the unions have thus faced the problem of coping with an almost infinite number of small and uncontrollable variations from schedule. A haunting fear of losing their solidarity has finally driven them to urge the adoption of legislation actually forbidding the practices of scientific management on government contracts. They have been so successful in securing the passage of the desired legislation that the carrying of a stop watch on a government contract is now considered as serious an offense as the carrying of any other concealed deadly weapon.

CONCLUSIONS

1. Muscular work may be carried on at such a rate that metabolites are removed at the same rate as energy is added tc the muscle. Such a muscle attains a "fatigue level" (Hough) after which it is in dynamic equilibrium, and may, theoretically, continue to work indefinitely (Figs. 1 and 3).

2. Of the three general methods that have been proposed for studying muscular fatigue, that of Hough (1901, IV, 3) suggests the most promising direction for further theoretical and practical experimentation (Fig. 2).

3. The work of Cannon and his students has suggested a physiological basis for the psychological conception of "reservoirs of energy" (James). According to Cannon sympathetic stimulation followed by the secretion of adrenin favors muscular activity by releasing bound sugar from the liver (hyperglycemia), by accelerating the heart and increasing blood pressure, thus favoring circulatory irrigation. These results complicate the entire problem of fatigue. It is suggested that certain extreme conditions of accumulated fatigue may be the result of adrenin poisoning.

4. Central fatigue has been demonstrated in the case of afferent and connecting neurones, but the rôle of the nerve cell body in central fatigue is not clear. In the present state of knowledge, the question of mental work appears to lie beyond the scope of physiology.

5. The physiological demonstration of a varying energy level renders the commonly accepted correlation between output and fatigue extremely doubtful and probably invalid. Individual output may fall as a result of normal fatigue or it may rise as the result of some emotional stimulus. The latter, if protracted, may lead to nervous breakdown.

6. The correlation between output and accident distribution is not a simple one. Statistical studies of accidents and output in the same group of workers are urgently needed before a definite conclusion can be reached (Fig. 6).

7. The psycho-physiological laboratory methods for studying fatigue have yielded almost no practical results when applied under industrial conditions. The reasons appear to be: first, laboratory subjects and industrial subjects are absolutely incomparable units; second, a condition approaching industrial fatigue never occurs

in the laboratory; third, the possibility of abnormal conditions in which sensitivity is reversed, as in certain psycho-neuroses have largely been neglected; and fourth, tests have been prematurely introduced under factory conditions without adequate previous theoretical study.

8. The term "industrial fatigue" is at present loosely applied either to the daily and weekly weariness resulting from industrial work or to the condition of accumulating fatigue which merges insensibly with psycho-neuroses. It would seem more logical to restrict industrial fatigue to the former more popular meaning and designate the gradually accumulating fatigue in overdriven industrial workers as *industrial psycho-neurosis.*

NOTES

1. Mlle. Ioteyko's *La Fatigue* in Richet's *Dictionnaire de Physiologie* gives a comprehensive review of the physiological aspects of the subject up to 1903.

2. This reaction is usually written the other way, as the esterification process, not the ester hydrolysis. (For further theoretical details of both reactions see Knoblauch, loc. cit.).

3. A detailed account of the researches that have led to the modern views of energy exchange in muscular activity will be found in Fletcher and Hopkins' Croonian Lecture for 1917 (II).

4. By "normally" we mean in the absence of special excitement or other emotional stress. (See "The Varying Energy Level" below.)

5. The sensations of weariness or sleepiness which accompany the performance of work are frequently considered to be reliable criteria of fatigue. In referring to the uncertainty of such subjective test, Rivers (1908, VII, p. 2) says, "In the performance of mental work especially, decided sensations of fatigue may be experienced when the objective record shows that increasing and not decreasing amounts of work are being done; and there may be complete absence of any sensations of fatigue when the objective record shows that the work is falling off in quantity or in quality, or in both."

6. The working rate in many of the older experiments was $\frac{\text{Contraction}}{\text{Relaxation}} = \frac{1 \text{ sec.}}{1 \text{ sec.}}$. This is usually written $\frac{C}{R}$.

7. Hough (1901, II) has shown conclusively that in the case of a trained muscle, the staircase phenomenon does not appear; the muscle contracts to its full capacity the first time. We have consequently considered our ordinates H to represent the maximum contractions. It should be pointed out that the staircase phenomenon is by no means constant. Mosso (1890, I) found it to be either positive or negative, for no clearly discernible reason.

8. The larger question involving the efficiency, not of a single reacting muscle but of composite groups such as we actually utilize in our daily tasks, presents a very much more complicated problem which we shall consider later on in our discussion of industrial efficiency (p. 40).

9. Cannon's work has been criticized by Dr. G. N. Stewart, in a number of recent papers. (See especially Am. J. Physiol., 44, 542.)

10. Dr. Lee has apparently not considered the possibility of the injurious effects resulting from an emotional overstimulation. He says (p. 102, loc. cit.): "During the war emergency special efforts should be made to stimulate the patriotism of the workers, and they should be made to realize that they individually have an important part to play in the winning of the war and in helping to establish the rule of right and justice." On the other hand, Florence (loc. cit.) expresses the attitude of the British Health of Munitions Workers Committee when he says (p. 84, loc. cit.): "Patriotic enthusiasm, as Professor Loveday points out, will stimulate men to keep at work when they are convinced of its urgency even though they are unwell and really need a rest"; and again (Vernon, Mem. 7, p. 15): "Misguided efforts to stimulate workers to feverish activity in the supposed interests of the country are likely to be as damaging to the desired result as the cheers of partisans would be if they encouraged a long-distance runner to a futile sprint early in his race."

11. The report of the work conducted by the U. S. Public Health Service in the munitions factories of the United States has not yet been published in complete form. (See Lee, 1918, VIII.)

PART III: BIBLIOGRAPHY

In the following bibliography we have omitted all but a few scattered references to the problem of fatigue in connection with education. We have also made no attempt to include the fatigue of the sense organs. The text references indicate the author, year of publication and number of the division in the bibliography in which the article is listed. We have adopted the following classification of titles:

I. General Discussion of Fatigue
II. Muscular Work and Neuro-Muscular Fatigue
III. Mental Work and Central Fatigue
IV. Tests for Fatigue
  1. General Discussion
  2. Sensations of Fatigue
  3. Dynamometric Measurements
  4. Sensory Threshold Fatigue
  5. Reflexes
  6. Chemical Reactions
V. Rhythms and Variables
VI. Correlation between Mental and Non-Mental Activity.
VII. Pathological Conditions
VIII. Industrial Fatigue and Efficiency

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IV. TESTS FOR FATIGUE.

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For special aspects of problems relating to scientific management and efficiency consult the Bibliographical Lists prepared by the Division of Bibliography, Library of Congress, especially No. 64.

TELEPHONE OPERATING: A STUDY OF ITS MEDICAL ASPECTS WITH STATISTICS OF SICKNESS DISABILITY REPORTS*

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NINE years' connection with the New England Telephone and Telegraph Co. have afforded the author most unusual opportunities both for studying telephone operating as an industry and for becoming acquainted with problems of personnel in telephone operating from the point of view of a physician.

The opportunities for study lie in examination of conditions in the telephone exchanges themselves; in the follow-up of special instances in which there is possibility of the presence of occupational disease; in the sifting of employees for admission to the school for telephone operators; in the re-sifting of those who have passed through the school before permanent placement in the exchanges; and in the analysis of individual problems involved in absences for ill health, in length of service, in dismissals, and in resignations from the service.

In taking advantage of the opportunity for studying the work in central telephone exchanges under all sorts of conditions, many problems of general hygiene have presented themselves. Consider, for example, the question of ventilation. At one time there was considerable enthusiasm on the part of a small group of people for solving the problem of ventilation by establishing ozone machines in the telephone exchanges. I was asked to investigate the value of the machines and later to convince these people of the findings. This was accomplished with the help of Professor Norton of the Massachusetts Institute of Technology. Samples of air were taken in a telephone exchange, both with the ozone machines in operation, and without, i.e., under the existing system of ventilation. These tests revealed the fact that the air in the exchange was good, and that the ozone machine had no effect whatever.

As is often the case, however, the incident gave opportunity for further experiment which was of real value. I had observed, in sitting before a telephone switchboard for a short time, during the busy hours when every position is filled, that the air between the operator and the board is poor. The switchboard is much higher than the operator's head, and she sits about two feet from it. Electric fans are arranged at frequent intervals at the top of the switchboard, at such an angle as to blow down in front of the operator and remove this air, but many girls, even in hot weather, object to the fans except for a very short while. We therefore took advantage at this time of the opportunity for having a test made of the air between the operators and the switchboard, with the result of discovering that a sample taken immediately in front of the operator contained more carbon dioxide after a fan had stirred up this air, than elsewhere in the exchange.

As a result, operators are now required periodically to stand at the board for from five to ten minutes at a time during the busy hours, while all the windows in the room are thrown open, and in this way, the bad air is removed.

The question of infectious diseases is also a problem of general hygiene to be considered in telephone operating. Throughout the exchanges an effort is made to prevent the spread of infectious diseases by having any employee, who has a disease of this nature in her household, stay away from work during the incubation period. She is paid for her lost time if she keeps herself from exposure by leaving home or if the patient is absolutely isolated. If she does not protect herself against infection, she is not paid. I have been interested to learn that boards of health, although prohibiting children from attending school if there is an infectious disease in the family, nevertheless permit an individual in the same family to work, even at an age when he is not beyond susceptibility to the same disease. The value

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of precautions is demonstrated by the infrequency of epidemics in the exchanges. One striking instance of bad results occurred when the precautions were neglected and several operators in a small exchange developed mumps. The trouble here was apparently due to an operator who worked during the incubation period, not realizing the importance of reporting to her chief operator the presence of the disease in her family. On one occasion, when diphtheria threatened one of the smaller exchanges, the operators were advised to have their susceptibilities tested by the Schick Test, and to take antitoxin if the results warranted it.

BENEFIT COMMITTEE

Another duty which I have assumed with great interest is the follow-up of all cases in which there is possibility of occupational disease. I have seldom found good evidence of occupation as the sole cause of any disordered condition found among telephone operators. The following case illustrates the value of thorough investigation. An operator had a persistent pain extending from the front of the ear down into the neck, always made worse when she wore her receiver. It was reported by an excellent general practioner and by an ear specialist, as an occupational disease, due to the pressure of the receiver. As the ear was in no way involved, disease of the ear, it seemed to me, should not be considered. I investigated an entire exchange of about 100 operators to see whether, in general, receivers were worn low enough to bring pressure on the spot where the pain in this case started. I found that such was the case among a small proportion of operators, although a receiver, accurately worn, is too high to bring pressure on the spot in question. I then sent the patient to another physician, who discovered that she had an infected tooth which had caused an enlargement of the gland in front of the ear. This was, of course, painful, and would stand no pressure. The removal of the tooth cleared up the occupational disease.

The possibility of brass poisoning of the skin and through the skin is a common belief among operators and apparently among some physicians. The plugs used at the switchboard to connect the subscribers' lines have brass tips, and at the base, a band of brass about one-quarter inch in width. The brass tip and band are supposed to be the cause of much trouble, although it is poor technique to pick up the plug by the brass tip because it necessitates shifting before the plug can be used. If, through carelessness, the cord or plug is used when it has become frayed or rough, there may result a mechanical irritation of the skin which might easily be the beginning of a dermatitis.

Generally, the so-called brass poison case is one of pus infection. There has, however, been one notable exception. A girl with a long-standing eczema of so severe a type that her skin had become permanently thickened and discolored, had a dermatitis of her fingers. A noted dermatologist concluded that the brass encountered in handling the plug was the irritant, although he admitted that he could find in the literature no record of skin poisoning from brass.

Occasionally, a dermatitis develops due to a preparation of acetone which is used by special clerks to remove fine lines painted on the switchboard. A cloth over a stick should be used, but sometimes a girl uses her fingers instead.

Stretching to reach the high multiple on the switchboard, which is often unfavorably commented on, has always seemed to me to be of real value in overcoming the discomfort of the constant sitting. The fact that the girl has to use both hands and arms is also of great advantage, both from the point of view of exercise and of dexterity with the left hand. It does occasionally happen, however, that pain in the lower right quadrant of the abdomen, due to chronic appendicitis, is increased by stretching, and is therefore attributed to stretching. There have also been a few cases of pain under the scapula, which I believe were probably due to subscapular bursitis. Such a bursitis, if not due to stretching, is unquestionably increased by it and a girl so affected should stop work until cured.

Accidents are practically never connected with telephone operating itself, but are usually due to blows from elevator or locker doors, and to falls.

While there are repeated opportunities for follow-up work in general and in special problems of this kind, the chief value of the author's nine years' experience in

telephone work has been the cumulative information acquired by observation, from a medical point of view, of large numbers of persons over a long period of time. During the last four years I have personally interviewed over 3500 operators, and have examined about 3000 operators in training before they were sent out to the different exchanges. The points of contact with the regular employees are through (1) the exchanges, (2) the Benefit Committee.

EXCHANGES

The particular part of the New England Telephone and Telegraph Co., with which I am connected is the Traffic Department of the Boston Metropolitan Division, where, in the fifty-two offices, are employed about 4000 operators, including chief operators and supervisors. Of this group, all employees who are absent over six days have to see me before returning to work, that I may judge whether they are able to work. If any employee has a poor daily attendance, and we include in this group any girl who has to stay out every month because of difficulty with menstruation, she is sent to me for advice. Any operator doing poor work and seeming to be in poor condition, even though she has excellent attendance and makes no complaint, should be sent to me by her chief operator. Any operator who wants medical advice—which may be simply to ask whom she should consult for any trouble that she has—is at liberty to come to me at any time. She may make the appointment through her chief operator, or may come without asking for an appointment.

BENEFIT COMMITTEE

The telephone company has a sick benefit plan, by which all operators who have been with the company two years or over, receive benefit; the payment, which is determined according to the length of service, beginning at the end of the first week. For from two to five years' service, the operator is entitled to four weeks' full pay and nine weeks' half-pay; five to ten years' service, thirteen weeks' full pay and thirteen weeks' half-pay; over ten years' service, thirteen weeks' full pay, thirty-nine weeks' half-pay. There is a Sickness Disability Report made out for every employee of the telephone company, who is obliged to be out for ill health over six days. This is forwarded to the Benefit Committee of the company to which she belongs. If her length of service is two years or more, her name is entered on the Committee's pay roll. If under two years, she is granted a leave of absence.

Any employee who is on the Benefit Committee's pay roll and is able to be out of doors, is asked to report to me for examination. If I am convinced she is unable to work, I may ask her to report to me as often as I think best until she is able to return to work. If I find she needs the attention of a specialist, or think she is not receiving proper medical attention, or that the case is not properly diagnosed, I have the privilege of sending her to a specialist or expert diagnostician, previously agreed upon by the Benefit Committee and myself, and the Benefit Committee pays the bill. Also, if I find no reason why the girl should not be back at work, and she and her physician think she is not able to work, I may send her to one of these physicians for examination. If he finds no reason why she should not be at work, the benefit is stopped, although her return to work is decided by her own physician.

The physician for the telephone company not only has the responsibility for the employees of the company, but is associated with the principal of the school for telephone operators, who is also the employment manager. The principal, Miss Mary E. Harrington, a woman of great experience and unusual ability in judging people, has herself managed a large exchange, and has studied and developed methods of training operators since the school was started, over ten years ago. Through our combined studies, essential points—physical and mental—which are the minimum requirements for the work, have been defined as a working basis.

In looking over the blanks used by many employers of labor, it has seemed to us that an elaborate, artificial scheme is too often used, without sufficiently definite application to the purpose. Our idea has been, having worked with large numbers over a long period, to profit by our mistakes and put all our attention on certain points which seem to be essential and which can be insisted upon. There are, of course, many things which we would like

to change, but before which we are powerless, such, for example, are the extremes in fashion so sure to be present in any large group of women, especially between the ages of 17 and 25. Very high heels unquestionably must have, sooner or later, a bad effect upon most girls, but to insist that a large group of girls shall wear unfashionable low heels and proper shoes has seemed to us impracticable.

PHYSICAL REQUIREMENTS

There are certain physical requirements which are demanded by the principal of the school for telephone operators and her assistants before accepting a student. The applicant must have a sitting height of 32 inches and an arm stretch of 60 inches in order to reach the high multiples of the switchboard. Her standing height and weight are taken as an estimate of her general condition. It is seldom, however, that disproportion of weight and height is sufficiently extreme to disqualify a girl for work. An examination of the eyes is very necessary for two reasons. If the applicant has absolutely no vision in one eye, it is impossible for her to do the work, because at a switchboard she cannot turn her head far enough to see on the side on which she has no vision. A girl who has been trained and has been unfortunate enough to lose the sight of one eye may get on very well, but we find it too great a strain for a beginner. If an operator is astigmatic, the row of jacks—small round holes—are probably a cause of eye-strain because of a constant effort to keep the holes and rows symmetrical. Close work, requiring the use of the muscles of accommodation, is really very slight. Any student who is subject to headache or who cannot read the fine type with either eye, is sent for an expert eye examination for which the company pays. The girl pays for her own glasses.

In examining a student her hemoglobin is tested as an indication of her general condition, particularly important in girls from 17 to 25, which is practically the age limit for beginners. No student would be excluded from the service because her hemoglobin was low, but she might be held over if it were extremely low, and, in order to avoid unnecessary fatigue, she would always be advised to do something to improve it.

Disturbances of the menstrual function, headaches and fainting are given consideration, both as an indication of the nervous condition of the individual and in order to impress on the girl that if she has to lose much time for any of these conditions, she can not be kept in the service. The opportunity is taken to advise students who have trouble of means of correction.

The ears are tested, and an applicant must have practically normal hearing in both ears because she not only has to use one ear for the receiver, but she must also be able to hear with the other anything that is said by her supervisor. Old middle ear disease with little impairment of hearing does not disqualify a girl for the work. We have, however, an expert examination to safeguard the girl, because if anything happens to her ears which incapacitates her for telephone work she has lost time which might have been better spent in some other employment not requiring such constant use of the ears.

The throat is inspected and any question of diseased tonsils, frequent colds, or trouble with the voice is settled by sending the student to a specialist and getting his diagnosis and advice.

The student is carefully questioned as to family history in regard to tuberculosis and as to her personal history for frequent colds or trouble with the lungs. If there is any questionable history whatsoever she is sent to a lung specialist for examination. If the girl is in good condition herself, a history of tuberculosis in the family or evidence of an old inactive process in her own lungs, would not debar her from the work.

The heart is examined, and if there is evidence of valvular disease the girl is allowed to enter the service unless there is some indication of lack of compensation. Before dropping a student for any cardiac disease, the advice of an expert is obtained.

The standard of nervous endurance and nervous adaptability of a girl for telephone work is the most difficult problem we have. We at one time asked Dr. William Healy about the desirability of using psychological tests. He was sure that certain tests could be worked out and made definite suggestions in this direction, but he doubted if a better percentage of re-

sults could be obtained than the employment manager already had. She has never fallen below 75 per cent. of successes among her admissions during the last four or five years, and generally has about 80 per cent. Dr. Healy's opinion is that no mechanical tests are of more value than good common sense, assuming, of course, that good sense is equivalent to a sound psychology supplemented by knowledge of the special subject and experience in successful application.

Professor Hugo Münsterberg once applied some psychological tests to a group of students in the school for telephone operators, which he has reported in his book, *Psychology and Industrial Efficiency*. He made the mistake, I believe, of approaching the problem with a too definite idea that memory is a more important factor than it is in the opinion of workers of long experience. The time interval between the reception and the use of a number is necessarily short, and the aids to memory so well provided by markings on the switchboard that memory without doubt plays a very unimportant part in telephone operating. Concentration, accuracy, self-control, and co-ordination are the most important factors. Of the students on whom the Münsterberg tests were made, 75 per cent. actually made good, while according to the tests, only 50 per cent. should have done so. Making good means passing the examinations of the telephone school for operators, remaining in the service, and reaching the standards set for the term of service.

The fine methods developed for training students before they are placed in the exchanges are a factor, not only economic for the industry, but also contributory to the health of the individual and to the morale of the force. This training goes on after the student leaves the school, and is accomplished by allowing the student operator to listen in with experienced operators, to operate herself under the supervisors when the incoming calls are comparatively few, and finally to be placed between good experienced operators. It is estimated that it takes at least a year and a half for the average girl to develop the highest standard of skill, for which adequate time and experience is allowed in this way.

The choice of students must be necessity be governed by the number and quality of the applicants, and this varies enormously in different sections of the country. Boston is probably exceptional, as there are always some hundreds of desirable applicants on the waiting list. With such a list to choose from, it is possible to select girls with at least one year of high school training and with good natural ability.

STATISTICAL RECORDS

The mass facts of interest in relation to the health problems of regular employees are shown through the very careful statistical records which the telephone companies make up once in six months regarding length of service, resignations and their causes, employees who have been dropped from service with the causes of dismissal, daily absentee records and any unusual conditions which may affect the whole working force. The 1918 report, for example, will probably not be as valuable in a study of this kind because of the abnormal conditions, i.e., the many resignations to enter government work, and the influenza epidemic, which enormously increased the number of daily absentees. During the height of the epidemic, from a daily average absentee record of 250, the number rose to 1080 in one day in the Boston Metropolitan District.

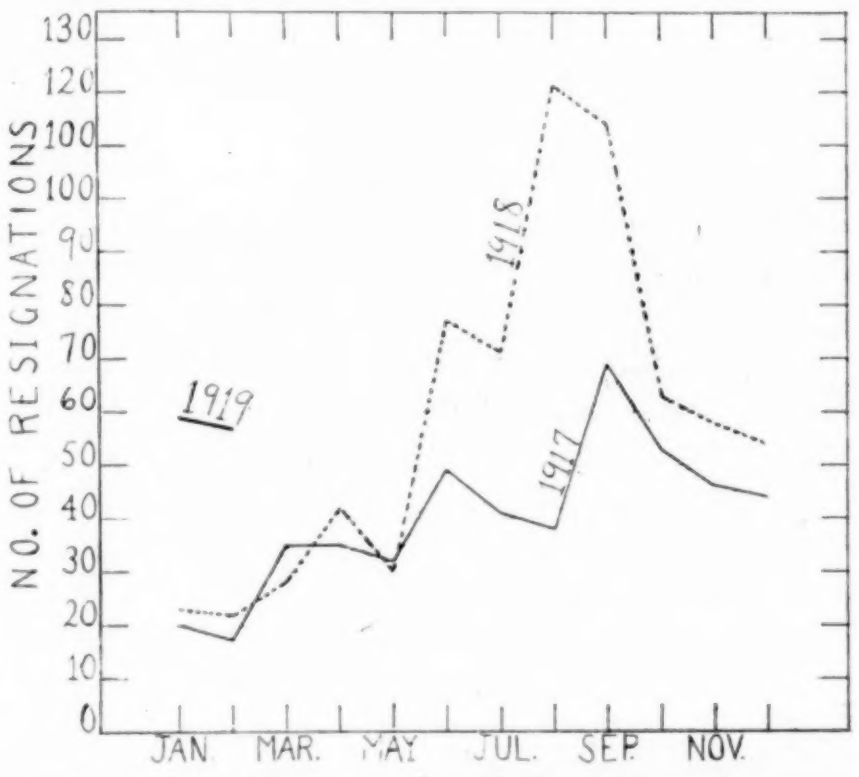

FIG. 1.—Curves showing the increase in the number of resignations of telephone operators in the Metropolitan Division of the New England Telephone and Telegraph Co. in 1918 over those in 1917.

Figure 1 shows the increase in resignations for 1918 over 1917, and Figure 2,

TABLE I

Average Length of Service and Percentage of Resignations, 1910 to 1918, Inclusive, of Employees in the Traffic Department of the New England Telephone & Telegraph Co., and in the Metropolitan Division of this Company.

Statistics Compiled in February	Average Number Months' Service, N. E.	Average Number Months' Service, Met. Div.	Per Cent Resignations N. E.	Per Cent Resignations Met. Div.	Per Cent Resignations Due to Ill Health, N. E.	Per Cent Resignations Due to Ill Health, Met. Div.
1910	36.3	41.4	.....	.....	.....	.....
1911	39.8	44.0	28.4	20.4	.....	.....
1912	41.2	46.1	25.6	17.0	4.0	2.6
1913	40.9	45.9	21.0	15.0	4.2	4.2
1914	44.7	48.5	14.0	10.4	2.4	1.6
1915	51.0	53.7	12.0	7.0	1.8	1.0
1916	54.5	56.2	11.2	6.4	1.4	1.0
1917	53.5	56.6	13.0	8.6	1.4	1.6
1918*	60.3	64.8	25.2	16.8	3.0	2.2

*Statistics for 1918 are the August instead of the February statistics.

the abnormal absentee record due to influenza. The second rise in the curve, which shows the second increase in influenza cases, covers a longer period of time and affects more people but the individual absence is generally shorter.

LENGTH OF SERVICE

Table I shows the average length of service of employees in the New England Telephone and Telegraph Company and in the Metropolitan Division of this company in months, for nine successive years, the percentage of resignations, and the percentage of employees resigning for ill health. The number resigning for ill health is known to be over- rather than under-estimated, because ill health is often a simpler excuse for the individual to give than the real cause, which may range from resignation for marriage to other employment.

Table I shows not only an increasing length of service, but also, even in 1910, an unusually long period of service for women employees. Women in industry change their work much more frequently than men, probably largely due to the fact that the great majority do not expect to stay permanently in the industrial world, but to marry. The percentage of resignations in 1918 again shows the abnormal conditions of that year.

STUDIES FROM SICKNESS DISABILITY REPORTS

In presenting the effects of the work on the different parts of the body which may be subject to strain in telephone operating, I have taken up the cases which have come to me personally and have compared my figures with the larger group of cases in the report of the Benefit Committee of the New England company, with the figures in the reports of the benefit committees of other large companies in the country, and with the figures in the reports of the benefit committees of the whole Bell system. I have chosen the 1917 reports for study, because at the time of writing the 1918 reports are not completed, and, as I have pointed out before, the 1917 figures are more valuable for study because of the abnormal conditions of 1918.

My group of cases includes employees of all lengths of service from a few months to twenty years. Out of an average force for 1917 of 3882, a large group, 37.3 per cent., had had a service of over five years. The following figures show the length of service of my group—employees of the Metropolitan Division of the New England Telephone and Telegraph Co.—on August 29, 1917:

	Less than 1 Yr. Service	1-2 Yrs.' Service	2-5 Yrs.' Service	Over 5 Yrs.' Service	Total
No. of employees	653	575	1203	1451	3882
Per cent employees	16.8	14.8	30.9	37.3	....

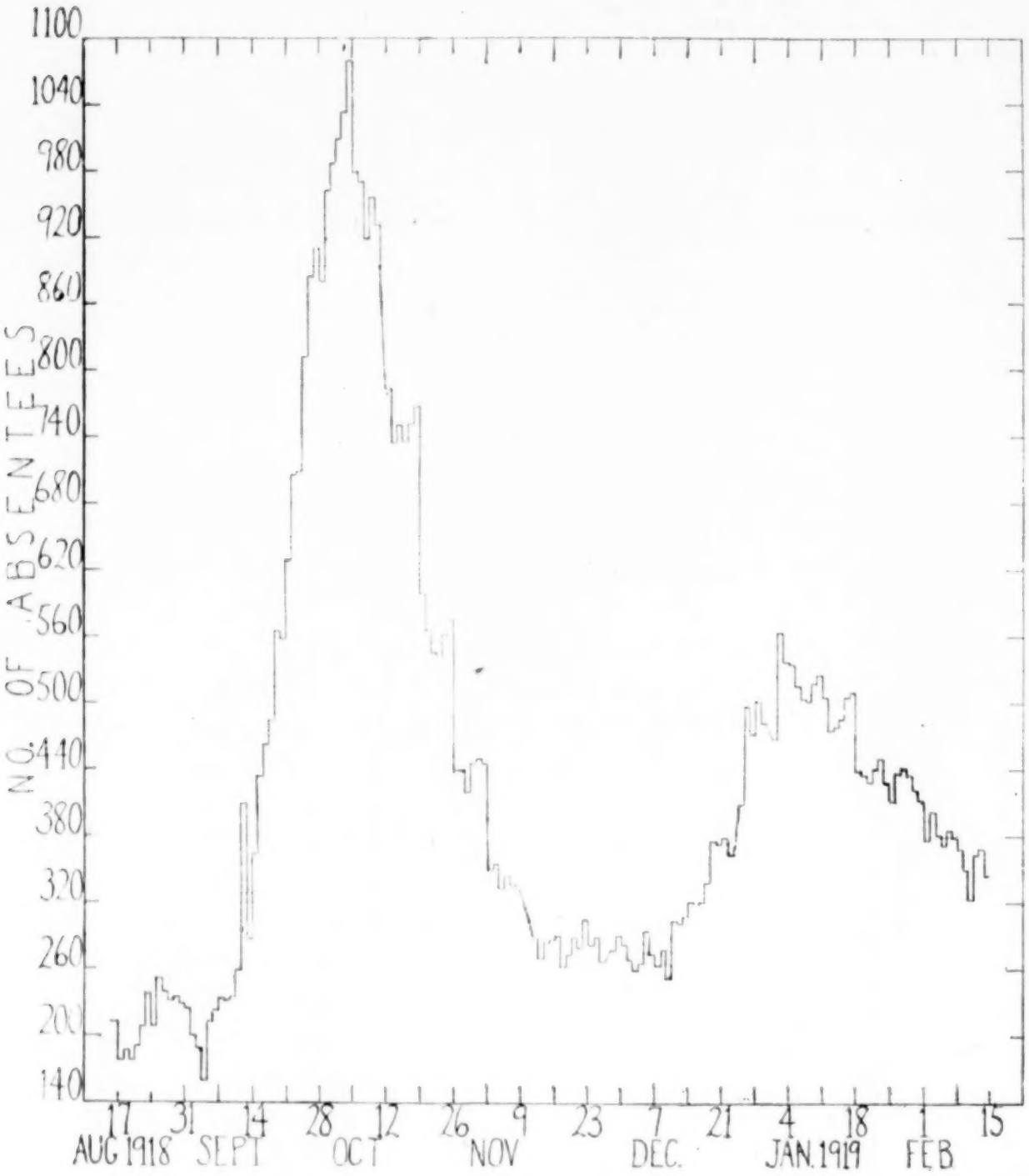

FIG. 2.—Curve showing the abnormal daily absentee record among telephone operators in the Metropolitan Division of the New England Telephone and Telegraph Co., during the influenza epidemic of 1918.

The cases tabulated in the report of the Benefit Committees include only employees who have been with the various companies two years and more. In evaluating the statistics of the Benefit Committees' reports, it must be remembered that the diagnoses in these cases are made by a large group of physicians of very varying ability. The classification is made largely by lay people on the Benefit Committees. This method of classification affects especially the group of ill-defined cases called *general debility*. These may be classed by one committee under the head of *neurasthenia;* by another under the head of *tuberculosis*, a physician having designated the cases as "pretubercular"; and by still another committee under the head of *acute gastritis*, because vomiting happened to be the first manifestation of illness.

In 1917, 1384 girls, out of a total of 3882, employees of the Traffic Department of the Boston Metropolitan Division, visited the staff physician. Table II shows the statistics of illness of employees of the large telephone companies of the United States, and of the total Bell system, which includes these six large companies and twenty-one other companies.

DISEASES OF THE EYE

A girl with astigmatism which has not been discovered and corrected before she goes to work, is very likely, as I have said before, to have eye-strain from looking at the jacks. There has been a good deal of comment made by people unfamiliar with

TABLE II

Statistics of Illness of Employees of Telephone Companies in the United States in 1917

Company	Average Number Female Employees Dec. 31, 1917	Total Number Female Employees Eligible for Sickness Disability, Oct. 1, 1917	Number Receiving Sickness Disability	Cases per 1000 Employees per Annum Eligible for Sickness Disability
N. E. Tel. & Tel. Co.	10,177	6,431	1,640	255.0
N. Y. Tel. Co.	20,165	11,323	3,541	312.8
Bell Tel. Co. of Penn	12,448	4,890	1,253	256.2
Chicago Tel. Co.	10,438	4,733	2,126	449.2
Pacific Tel. & Tel. Co.	9,960	4,654	931	200.0
Total Bell Tel. System	127,484	55,277	15,000	271.4

the switchboard, on the strain of flashing lights. The lights are of fractional candle-power, and are covered with thick ground glass which is sometimes colored. Any strain to the eyes from these lights would be impossible, but the fact that the flashing of a light indicates to the operator that there is an impatient subscriber does have an effect upon her general nervous system.

In 1917 thirty-one girls in my group had some trouble with their eyes. Iritis and acute conjunctivitis make up the acute inflammations. In my experience there has never been a syphilitic iritis or a gonorrheal conjunctivitis. In the statistics compiled by the Benefit Committees there were probably no refractive cases, because absence for this cause alone would not be long enough to be reported.

The following figures show the disorders of the eyes occurring among the operators of the Boston Metropolitan Division in 1917:

	Length of Service				Total
	0–1 Yr.	1–2 Yrs.	2–5 Yrs.	5 Yrs.	
Acute Inflammation	..	2	9	1	12
Errors of Refraction	4	2	12	..	18
Meibomian Cyst	..	..	..	1	1
					31

Table III gives the statistics of eye diseases of the operators of the large telephone companies of the United States and of the total Bell system.

TABLE III

Eye Diseases

Company	No. Eye Diseases	Cases per 1000 Employees per Annum Eligible for Sickness Disability
N. E. Tel. & Tel. Co.	15	2.3
New York Tel. Co.	22	1.9
Bell Tel. Co of Penn.	14	2.9
Chicago Tel. Co.	26	5.5
Pacific Tel. & Tel. Co.	10	2.1
Total Bell Tel. System.	146	2.6

DISEASES OF THE EAR

The receiver, which is held over the ear by a steel band passing up over the head, sometimes causes excoriation of the external ear. This condition is especially likely to occur in a beginner who thinks she must have the receiver very tight over the ear in order to hear, but it is rarely found among experienced telephone operators.

During my nine years' service there has been one interesting case of hysterical deafness. The girl in question had a loud noise in her ear, which, for a time, apparently caused complete deafness. After careful examination by a neurologist and by an aurist, the diagnosis of hysterical deafness was made. She soon recovered the hearing of one ear, but when last heard from insisted that she could not hear in the other.

A curious nervous condition which has been noted in a very few students is that of inability to hear with the receiver in place, although there is no disease or defect of the ear. In these cases mechanical relief was attempted by change of position and instrument but without results.

There have been astonishingly few employees who have had sufficient deafness to oblige them to give up the work. In general, attention is so trained that experienced operators almost invariably think that their hearing has become more acute.

There were thirty-three cases of ear trouble in my group during 1917. The following figures give the details:

	Length of Service				Total
	0 1 Yr.	1-2 Yr.	2-5 Yr.	5 Yr.	
Acute Middle Ear Inflammation	2	3	7	11	23
Chronic Middle Ear Inflammation	1	..	1	4	6
Disease of External Ear and Canal	1	1	1	1	4
					33

Table IV gives the statistics of the ear diseases occurring among the operators of the large telephone companies of the United States and of the total Bell system.

TABLE IV

Ear Diseases

Company	No. Ear Diseases	Cases per 1000 Employees per Annum Eligible for Sickness Disability
N. E. Tel. & Tel. Co.	25	3.9
New York Tel. Co.	43	3.8
Bell Tel. Co. of Penn	14	2.9
Chicago Tel. Co.	24	5.1
Pacific Tel. & Tel. Co.	9	1.9
Total Bell Tel. System	167	3.0

DISEASES OF THE NOSE AND THROAT

Diseases of the larynx are the most important division of this group from the point of view of the effect of the industry. There have been three cases diagnosed as singer's nodes. One of these cleared up in so short a time that a consulting laryngologist decided that the case was one of acute inflammation rather than of singer's nodes. The second case was that of a girl who had been with the company a very short time, not more than two or three months. This girl was obliged to resign and seek other occupation, as with a throat so delicate she was clearly not fitted for telephone work. In the third case the girl had been operating for over five years when she began to get hoarse. She was out on sick leave for two months and when she returned was given clerical work. She still has a very husky voice, although it is more than two years since she stopped telephone operating. Mrs. May Sleeper Ruggles, a vocal music teacher to whom this girl was sent by her physician, called attention to the fact that, since only a few short sentences are used, and these used repeatedly, the voice is confined in telephone operating to a very limited range. To counteract this evil she advised practising scales. This advice, together with suggestions for forward placement of the voice, I have passed on to many girls with poor voices. It would, perhaps, be better to insist that girls with chronic laryngitis do some other work, but there have been no other cases which seemed sufficiently severe to warrant this.

The hysterical aphonias have been very interesting. Some years ago in two different exchanges there occurred a number of cases. In both places the conditions were very similar. The series of cases was started with loss of voice due to acute laryngitis in a girl, who, because she felt well, was allowed to stay in the exchange and do clerical work. Following this, four or five girls suffered loss of voice with no physical cause which could be discovered by throat specialists. Two cases in this series occurred in the same exchange and were quite unusual. One was so extreme that it was diagnosed at the Massachusetts General Hospital as a psychosis, and it seemed to me probable that it was due to occupation. For this reason a change of occupation was advised and the patient resigned. Several months later she came to ask another trial, because she could find no work she liked as well. Having learned in the meantime that this girl had lost her voice before she ever did telephone work, I decided to give her another trial. This happened over five years ago and she has had no trouble with her voice since. The other case was of a girl of rather pronounced hysterical type. When she returned to work after recovery from her loss of voice she feared she would have trouble unless her position at the board was changed. Several times afterward she had trouble for a short time, an hour or two, and once was sent immediately to me. When she came in to speak to me her voice was all right, and she told me this story. She had gone into the retiring-room and a friend had said to her, "Don't go near Miss Smith, she has lost her voice and you'll lose yours." In spite of this warning, she went over to speak to Miss Smith, but could not say a word. She has had no trouble for two or three years.

The small number of these cases—and in telephone work cases of this kind cannot escape notice—raises the question whether they are really out of proportion among telephone operators. Some light might be thrown upon this matter if the occupations of all the patients with hysterical aphonia could be studied in a large clinic. It is now the rule in the telephone company to send home a girl who loses her voice, and the difficulty of a group of cases has never been repeated.

In my group, during the year 1917, there were 349 cases of trouble with the nose, throat and larynx. Many of these patients had had operations on the nose which seemed to have been ill-advised, and on the

TABLE V
Diseases of the Nose and Throat, Boston Metropolitan Division

	Length of Service				Total	
	0-1 Yr.	1-2 Yrs.	2-5 Yrs.	5 Yrs.		
Operations on Nose	2	7	9	7	25	
Acute Choryza	12	12	28	24	76	
Chronic Catarrhal Inflammation	1	3	11	13	28	
Atrophic Rhinitis	..	2	6	4	12	
Tonsillitis, Acute	14	14	46	40	114	39.7
Tonsillitis, Chronic, Operated	3	6	15	9	33	per
Tonsillitis, Chronic, not Operated	1	1	4	1	7	1000
Laryngitis, Acute	5	10	14	13	42	
Laryngitis, Chronic	1	..	1	1	3	
Aphonia	1	3	2	3	9	
					349	(89.9 per 1000)

whole to have caused more discomfort than the ill-advised tonsillectomies. There have been, on the other hand, many operations for diseased tonsils after which there has been a great improvement in the health of the patients. It is my custom to advise girls to secure the advice of two specialists before submitting to an operation on the nose.

Atrophic rhinitis is a disease which often necessitates resignation from the telephone service because the odor is so intolerable and the disease usually so slow of cure.

The table made up from the reports of the Benefit Committees shows only acute and chronic operative tonsillitis. My percentages exceed the percentages in these reports because they include more types of disease, and also a certain number of girls asking advice, who were not out on disability.

Unfortunately, the Benefit Committees have not included laryngitis in their special diseases for tabulation. Probably the number of cases sufficiently severe to cause absence for over one week was small, and therefore seemed unimportant.

Table V summarizes all the cases of disease of the nose and throat in the Boston Metropolitan group.

Table VI gives the general statistics of tonsillitis among operators of the large telephone companies of the United States and of the total Bell system.

TABLE VI
Tonsillitis

Company	No. of Cases	Cases per 1000 Employees per Annum Eligible for Sickness Disability
N. E Tel. & Tel. Co.	219	34.1
New York Tel. Co.	316	27.9
Bell Tel. Co. of Penn.	138	28.2
Chicago Tel. Co.	325	68.6
Pacific Tel. & Tel Co.	136	29.3
Total Bell Tel. System	1,773	32.1

DIGESTIVE DISTURBANCES

I believe that with all girls between the ages of 18 and 25 digestive disturbances are very common, due to the fact that there

TABLE VII
Gastro-Intestinal Disturbances, Boston Metropolitan Division

	Length of Service				Total
	0-1 Yr.	1-2 Yrs.	2-5 Yrs.	5 Yrs.	
Appendicitis	2	3	1	4	10
Appendicitis, with Operation	4	4	16	15	39
Gastric Ulcer	1	....	....	....	1
Cholecystitis, with Operation	....	....	....	1	1
Cholecystitis, without Operation	....	....	....	2	2
Ptosis of Abdominal Organs	....	....	1	5	6
Indigestion, including Constipation	6	11	42	31	90
					149

is great irregularity in eating, in care of the bowels, and often very unwise choice of food. It has to be remembered that telephone service must be available night and day, Sundays and holidays, and that the service has great variation in different hours of the day. For this reason, a certain number of operators have to begin work at very early hours and these girls are apt to do without breakfast and to eat lunches, very likely with tea or coffee, in the morning and in the afternoon relief and in the lunch period. It is, however, true that girls with the most desirable hours do the same thing, and that some girls choose the early hours because they like them. The early hour work should, however, be recognized as a condition of this industry which may contribute to digestive disturbances.

Table VII summarizes the gastro-intestinal disturbances of employees of the Boston Metropolitan District in 1917. In my opinion, gastric ulcer is probably more common than appears in this table, but it is seldom that satisfactory diagnoses are sent in by physicians attending the girls in their homes.

TABLE VIII

Digestive Disturbances, Including Diseases of the Stomach and Appendicitis

Company	No. of Cases	Cases per 1000 Employees per Annum Eligible for Sickness Disability
N. E. Tel. & Tel. Co. .	198	30.8
New York Tel. Co. . . .	298	26.4
Bell Tel. Co. of Penn. .	110	22.5
Chicago Tel. Co.	122	25.8
Pacific Tel. & Tel. Co. .	78	16.7
Total Bell Tel. System .	1346	24.4

Table VIII gives the statistics of digestive disturbances occurring among the operators in the large telephone companies of the United States and the total Bell system.

TUBERCULOSIS

In looking over the reports of the different companies, it is noticeable that the percentage of tuberculosis in the New England company is 7.6 as against 4.7 per cent. or less in other companies. This seems a difference so great as to require explanation. It is probably both a question of diagnosis and of classification. In the Metropolitan Division, for example, which represents over one-third of the New England company, it is the custom to send for an expert examination any girl who, from no apparent cause, has lost weight or is feeling tired. This naturally leads to the discovery of early tuberculosis and of so-called pre-tubercular cases. These have, as a matter of fact, been classified as tuberculosis in the New England committee's group and no doubt account for the large percentage. It should be noticed too that the New England company in spite of the larger percentage of cases, has, probably as a result of early diagnosis, a low death rate of 4 per cent., as against 8 per cent. of the whole Bell system.

TABLE IX

Tuberculosis, Boston Metropolitan Division

	Length of Service				Total
	0–1 Yr.	1–2 Yrs.	2–5 Yrs.	5 Yrs.	
No. Cases . .	1	3	11	6	22
No. Deaths	. .	2	2	. .	4

TABLE X

Tuberculosis

Company	Number of Cases	Cases per 1000 Employees per Annum Eligible for Sickness Disability	Number of Deaths
N. E. Tel. & Tel. Co.	49	7.6	2
New York Tel. Co.	48	4.2	7
Bell Tel. Co. of Penn.	22	4.5	5
Chicago Tel. Co.	18	3.8	2
Pacific Tel. & Tel. Co.	22	4.7	0
Total Bell Tel. System	256	4.6	21

In 1917, 163 girls in the Boston Metropolitan Division were sent to a specialist for examination of the lungs. Of these, twenty-two had active trouble, twenty-six had enlarged bronchial glands, forty-four had an old inactive process, and the rest were negative. There were four deaths, two of whom had a service of less than two years and so do not appear in the report of the Benefit Committee of the New England company. This was an unusual number of deaths, two being the greatest in any one year up to 1917, but I have an impression that in 1918 there was an increase both in the number of cases and in the deaths.

Table IX gives the tuberculosis statistics for the Boston Metropolitan District for 1917.

Table X gives the general statistics of tuberculosis among operators in the large telephone companies of the United States and in the total Bell system.

NERVOUS DISEASES

The classification of this group of cases is very difficult, because telephone operators have shown very few organic diseases of the nervous system and the symptoms which do occur are so largely subjective that it is difficult to know just where the emphasis should be placed. A study of the statistics of different Benefit Committees' reports shows a very marked variance in the percentage of cases. Neurasthenia, which is the diagnosis adopted, is evidently used to include all types of nervous fatigue. The typical neurasthenic is generally unfitted for telephone work. A large majority of the operators in this group whom I see are cases of simple fatigue. A small percentage have some marked symptom, such as insomnia, emotional disturbances, tremors, or occasionally chorea.

During my whole service I have known of but five cases of insanity; one of these was a very pessimistic girl, who enjoyed talking of suicide and imagining horrors but who did not have delusions. For this reason, I have ventured to doubt the diagnosis of insanity which was made by a good psychiatrist, who however, interviewed the patient only once. Two of the insane patients have recovered. One of these, a girl with acute melancholia, had had sufficient family trouble to upset a person of much better poise, and has, I believe, permanently recovered. The other patient may, I fear, have other attacks, as she is a girl of poor judgment and has a family history of insanity. The remaining two insane patients probably have little hope of recovery: one is a case of dementia praecox, and is the second member of her family to have the disease: the other patient has shown very little improvement although under hospital care for three years.

Table XI summarizes the cases of nervous disabilities in the Boston Metropolitan District in 1917.

TABLE XI
Nervous Disabilities, Boston Metropolitan Division

	Length of Service				Total
	0-1 Yr	1-2 Yrs.	2-5 Yrs.	5 Yrs.	
Fatigue, without Definite Symptoms	17	16	65	84	182
Fatigue, with Definite Symptoms	..	..	..	2	2
Insanity	..	..	1	..	1
Neuralgia	..	2	2	..	4
Neuritis, Pain with Tenderness	1	1	1	..	3
Facial Paralysis	..	..	1	..	1
Occupational Neurosis	..	..	1	..	1
Neurasthenia	..	1	1	..	2
Hysteria	3	..	13	2	18
					214 (55.1 per 1000)

Table XII gives the statistics of nervous disability among operators in the large telephone companies of the United States and in the total Bell system.

As Group 2 (fatigue with definite symptoms) in my table is unusually small, I think possibly some cases classified as simple fatigue should belong here—cases which were probably seen late when they did not present the more severe symptoms.

From the standpoint of the hygiene of

TABLE XII

Nervous Disability, Including Neuralgia and Neurasthenia

Company	No. of Cases	Cases per 1000 Employees per Annum Eligible for Sickness Disability
N. E. Tel. & Tel. Co. . .	129	20.1
New York Tel. Co.	631	55.8
Bell Tel. Co. of Penn. . .	202	41.3
Chicago Tel. Co.	140	29.6
Pacific Tel. & Tel. Co. .	90	19.3
Total Bell Tel. System.	1845	33.4

telephone operating, the group which I have classified as simple fatigue seems to me the most important and the most difficult to study. As the length of service increases, the percentage of these cases increases. At the end of two years when an employee is entitled to sickness disability payment, the percentage, which has been about the same for the first two years, nearly doubles, and it also increases somewhat in operators of over five years' service. In this group of cases there are a certain number of girls who are excellent workers, reliable, and in every way valuable employees, but who have not the nervous energy to work fifty weeks in the year. I doubt if these girls form 1 per cent. of the whole group. Another group is made up of girls who have very poor endurance; they give up for every ill, and so have a poor daily attendance, but both work and attendance are not quite bad enough to cause them to be dropped from the service. Such girls always have a long convalescence from any real illness, and the excuse is given of a "run down condition." As long as they can afford to remain idle there seems to be no incentive to induce them to go to work. I find, as they report to me weekly, that they either make no progress or that they lose in weight, become more anemic, have no appetite, and sleep poorly. Improvement often follows going back to work.

Another type in this group of cases is the girl who has "gone stale." I suppose no person with brains and with imagination escapes this, but some have it worse than others. It is most common among the operators who have worked five to ten years. Some conditions which I think may account for this are, first, reaching the age of 23 to 30 without marrying; second, the lack of ability or ambition to advance; third, home conditions or temperament which make recreation difficult. In the really tired-out group, there is a large number who have excessive family obligations and a few who burn the candle at both ends in order to have a good time.

Hysterias are mostly of the ordinary type; lack of control and semi-unconsciousness. The one case of occupational neurosis in this group is another instance in which the subsequent history disproves the diagnosis. The girl in question had a pain in her neck which was diagnosed after a careful examination by a neurologist as a neurosis due to pressure of the receiver. After a rest the pain disappeared, and when the girl returned she was given clerical work to do. After a year of clerical work, which required neither the wearing of receiver or transmitter, the patient was again in poor condition and the old pain returned. No definite cause for the pain was ever discovered, but it was found that she had very trying home conditions, the burden of which she had to bear alone.

As will appear from the records of cases, diseases attributable to the work alone are very rare. It is a question whether it will ever be possible to eliminate the percentage of girls who have not the kind and the amount of endurance to do telephone work, or to persuade those who have tried it and are unsuited, to do something else. The greatest cause of nervous strain lies in the inevitable irritations to be found in every personnel. It is hardly possible to arrange a force so that no employee shall come in contact with an uncongenial superior, or so that absolute justice shall be meted out to every individual.

The ordinary methods for the measuring of fatigue, applicable to work which is largely mechanical, are not of value in telephone operating, because there is such a large human element on all sides. The *A* operator, who answers the subscriber's signal, for example, may be stimulated or emotionally upset by the tone of voice of the subscriber, or by her supervisor, or by the *B* operator, to whom she passes the call. The *B* operator, on the other hand, does not have the subscriber to deal with, but she does have the supervisor and the *A*

operator. An operator with no fatigue may, on one occasion, have very many errors from a temporary emotional disturbance; at another time, the same operator may be stimulated by some emergency to do very good work even when fatigued.

Chief operators and supervisors, too, are very human and have to stand the brunt of the criticisms of both the subscribers and of the officials of the company.

In telephone operating it is necessary to have what are known as service tests. In no other way can the standard of service be kept up and justice be done to the public and to the operators. These tests may not always have been wisely used in the past and may have constituted a source of nervous strain, but with the present methods very little misuse is possible.

The amount of concentration needed to do good telephone work is, of course, a consumer of energy, but on the other hand concentration unquestionably develops nervous control and nervous endurance. I doubt very much if it is ever the chief cause of nervous breakdown.

The careful preliminary training which teaches an operator what to do on all occasions, the arrangement of the switchboard for good team work, and the fact that on the whole the work does not hold over, are the greatest safeguards against nervous strain.

The monotony which must come to all individuals who work for compensation should, I think, be corrected during the worker's free time; the problem of the employer should be to see that there is sufficient free time to counteract any strain.

In telephone operating the hours of work vary because of the necessity of a twenty-four hour service and because of the great variation in the amount of business at different hours of the day. Advantage in time is given to those who work after 7 P. M. There are four types of service: the straight day, the divided hour, the short hour, and the all night. Every period of work is broken by a fifteen minute relief for operators and a twenty minute relief for the supervisory force. In the city offices the day is eight and three-quarters hours, out of which are taken two fifteen minute reliefs and three-quarters of an hour for lunch, leaving seven and one-half hours' labor. Lunch can be bought at cost on the premises, saving time and making it possible to spend more time out of doors. In the out of town exchanges one hour for lunch is given, because the girls prefer to go home for lunch, but the hours for labor are the same, seven and one-half. The divided hour duty, or "split trick" as it is called, has a morning and evening service, i.e., one service of three hours and one of four, or two services of three and one-half hours each. Out of each service is taken a fifteen minute relief, leaving six and one-half hours for labor. These hours must be arranged so as to give not less than eleven and one-half hours between stopping work at night and beginning in the morning. The short hour trick is either 4 to 10 P. M., or 5 to 11 P. M., with a half-hour relief, making five and one-half hours' labor. The all-night operators' hours are from 11 P. M. to 7 A. M., with an hour and a half relief, making six and one-half hours' labor.

Very careful studies have been made by skilled engineers, watching conditions in an exchange and listening in on positions, to note every possible variation in an individual's work in order to determine what proportion of time an operator can work well, i.e., render the best service to the public with the fewest possible errors and with the least possible physical and nervous strain. In this way standards have been established which are technically called *loads*. These vary for different types of operators. The *A* and *B* operators are occupied during the busiest hours 50 to 85 per cent. of the time. This variation is necessary to allow for sudden emergencies. For short periods the work often falls below 50 per cent. of time occupied, but it is found that if it stays much below 50 per cent. for any length of time the service is invariably poorer. There is, however, probably no group of workers who, confronted with an emergency, respond with more enthusiasm and ability than telephone operators. This has been instanced again and again in Boston and in the vicinity in great public emergencies, such as the Chelsea and Salem fires and the influenza epidemic, and there are from day to day in the exchanges countless smaller emergencies for which preparation is impossible and where individual and group morale are tested to the full.

BOOK REVIEWS

Italian Women in Industry. A Study of Conditions in New York City. By Louise C. Odencrantz. Cloth. Price, $1.50 net. Pp. 345. New York: Russell Sage Foundation, 1919.

This book reports an intensive study of a section of our Italian population in New York City. The work was begun in 1911 and finished in 1913. During this time 1095 women wage-earners were interviewed, 2727 calls being made; the living conditions of 544 families were recorded and a study made of the weekly budgets of 147 women, not living at home. A careful record was kept of the total annual income and the expenditures of forty-eight of the families. The investigators also followed the women into their places of work, visiting 271 manufacturing establishments out of the 734 employing the group of women studied. All but twenty-seven of the women lived in the Italian districts below Fourteenth Street, and over three-fourths, 772, were in the lower west side colony in the neighborhood of 28 Macdougal Street.

The occupations followed by the group were:

Manufacturing	1027
Trade and Transportation	55
Professional service	7
Domestic and personal service	6

Seventy-five industries were represented in the manufacturing group, by far the largest number consisting of the manufacture of various articles of clothing. Paper box making, candy making, laundry work, flower and feather making and tobacco trade are also included, so that the list is fairly comprehensive.

The studies made cover the following phases of the lives of these women:

1. The Women and Their Families.
2. Occupations of Italian Women at Work.
3. The Work Places of Italian Women.
4. Hours of Work.
5. What Seasons Mean to the Worker.
6. The Pay Envelope.
7. Ups and Downs of the Family Budget.
8. The Woman Who Does Not Live at Home.
9. Education and Training.
10. Readjustment.

The picture one obtains from this report of hopeless repetitive work, of uncertain tenure of positions from which no advance is possible, and of impossible living conditions cannot fail to act as a severe indictment of our methods of handling labor. The women studied represent one-third of the working force in the establishments investigated, and the conditions they are facing must also affect women from other countries. Many of the women studied had been in the United States since childhood and had had no opportunity for real Americanization. No facts were elicited showing fundamental defectiveness for citizenship in these Italian women. The facts showed that they had become rather helpless parts of a great machine, the movements of which were far beyond their comprehension.

A conspicuous feature brought out by the investigations is the almost complete lack of anything approaching health supervision. Not only are these women placed in a position from which it is impossible for them to rise, but their health is so far jeopardized that they, themselves or their children, cannot fail to become a source of unemployable individuals.

The remedy lies, first, in education through trade unions, clubs, settlements, evening schools and, most important of all, in the efforts of far-seeing employers. The uncertainties of employment and the opportunity to find suitable work should be safeguarded through employment bureaus such as we may expect to have through the United States Employment Service. Considered simply as labor, with no question of the humanitarian side of the matter, one cannot but feel that this report pictures these Italian women as a certain liability in the labor market. If we could but realize that they are a valuable and perishable economic asset, the gain to the country would be great.—*Katherine R. Drinker.*

Physical and Occupational Re-Education of the Maimed. By Jean Camus with the collaboration of A. Nyns, Bourrillon, F. Terrien, E. Fontane, Nóve-Josserand, Bourget, Boureau, P. Larue, A. de Mazières, E. Leroux, P. De Cabaussel, E. Voron, J. Nanot, P. Lindemans, Belot, Private, H. Nepper, and C. Vallée. Authorized translation by W. F. Castle, Surgeon, R. N., with articles on British institutions by Sir Arthur Pearson, Bart., Margaret Sale, and Dudley B Myers. Cloth. Price, $2.00. Pp. xi., 195, with illustrations. New York: William Wood & Company, 1919.

This is a brief and non-technical account of the efforts toward the re-education of disabled soldiers now being made in France, Belgium and England. Its chief value lies in the sensible and courageous view it presents of a task, large and perhaps discouraging. Thus, at the outset the statement is made that physio-therapy must not be prescribed like quinine, but always psycho-therapy must go with it. And so, through the entire book, one is reminded that in the disabled soldier we have a new type of individual, who must be led into new work by the most adroit means at the disposal of the educator.

Brief accounts summarize various types of work, such as agricultural work, basket-making, silk production, dairy work, mechanical training, etc.

It is regrettable that the numerous pictures which accompany the text are frequently so indistinct as to be of no value.—*Cecil K. Drinker.*

BOOKS RECEIVED

Dispensaries, Their Management and Development. A Book for Administrators, Public Health Workers, and All Interested in Better Medical Service for the People. By Michael M. Davis, Jr., Ph.D., Director of the Boston Dispensary, and Andrew R. Warner, M.D., Superintendent of Lakeside Hospital, Cleveland. Cloth. Price $2.25. Pp. 438, with illustrations. New York: The Macmillan Company, 1918.

Colloid Chemistry. An Introduction, with Some Practical Applications. By Jerome Alexander, M.Sc., Chairman, Special Committee on Colloids, Division of Chemistry and Chemical Technology, National Research Council, Member Amer. Institute Chemical Engineers. Cloth. Price $1.00 net. Pp. 90, with illustrations. New York: D. Van Nostrand Company, 1919.

Creative Impulse in Industry. A Proposition for Educators. By Helen Marot. Cloth. Price $1.50. Pp. 146. New York: E. P. Dutton & Company, 1918.